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SURGERY

A Monthly Journal Devoted to the Art and Science of Surgery

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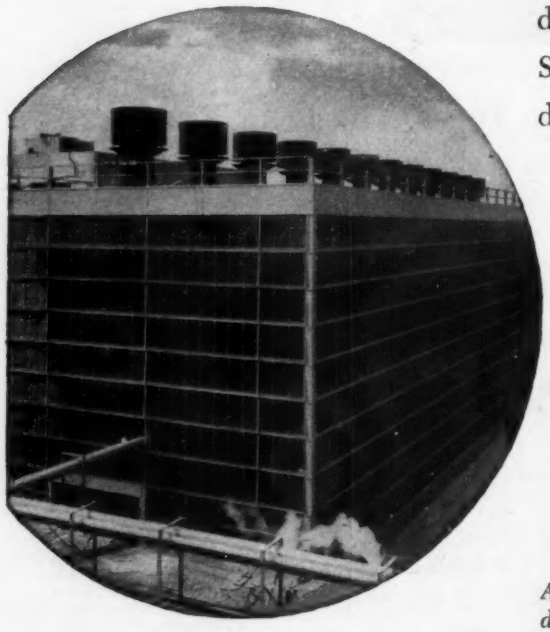

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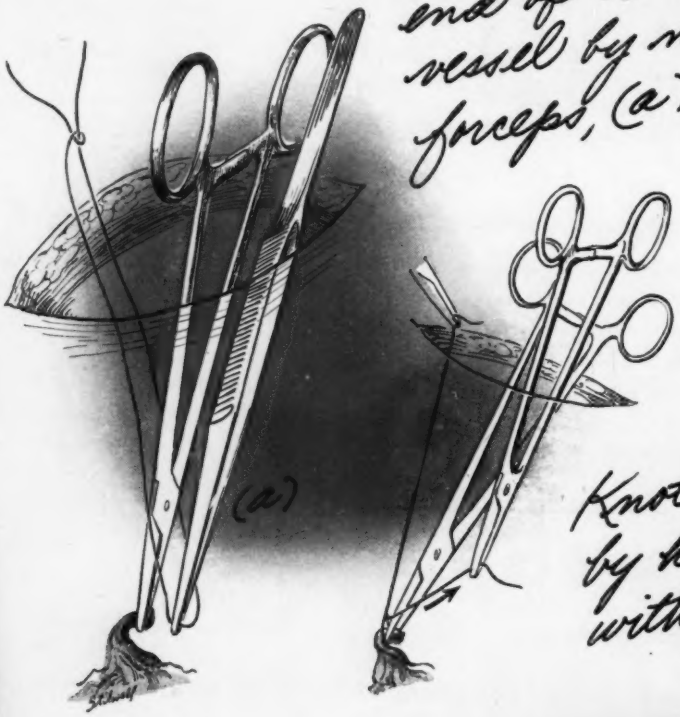
Setting the first knot

Setting the first knot often presents a difficult mechanical problem. Working deep in a hole — suture must have sufficient thread strength to tighten first knot.

Three methods can be used

1. Suture placed over end of clamped vessel by means of forceps, (a)



(a)

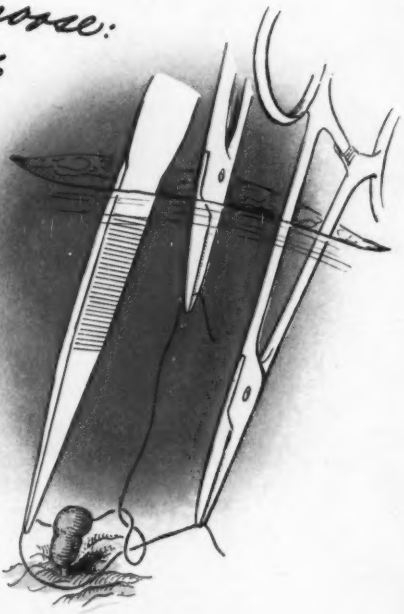
(b)

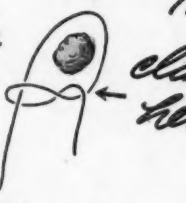
Knot tightened by hand or with clamp, (b)

SUTUREGRAM NUMBER FOUR (CONTINUED)

(2) By special slip noose: Clamp places loop accurately over structure to be ligated

Example: small rectal polyp.





(3) Tissue to be ligated is transfixed by suture. Knot tied out of hole and tightened down toward this point of fixation.

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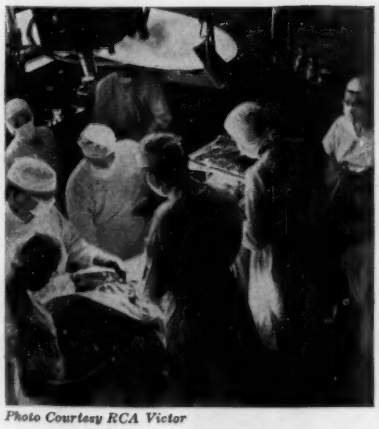

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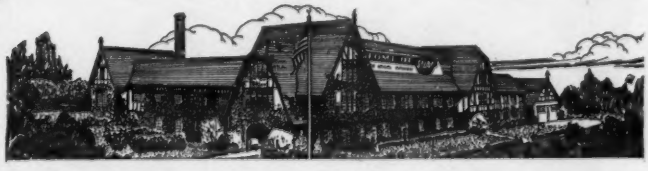

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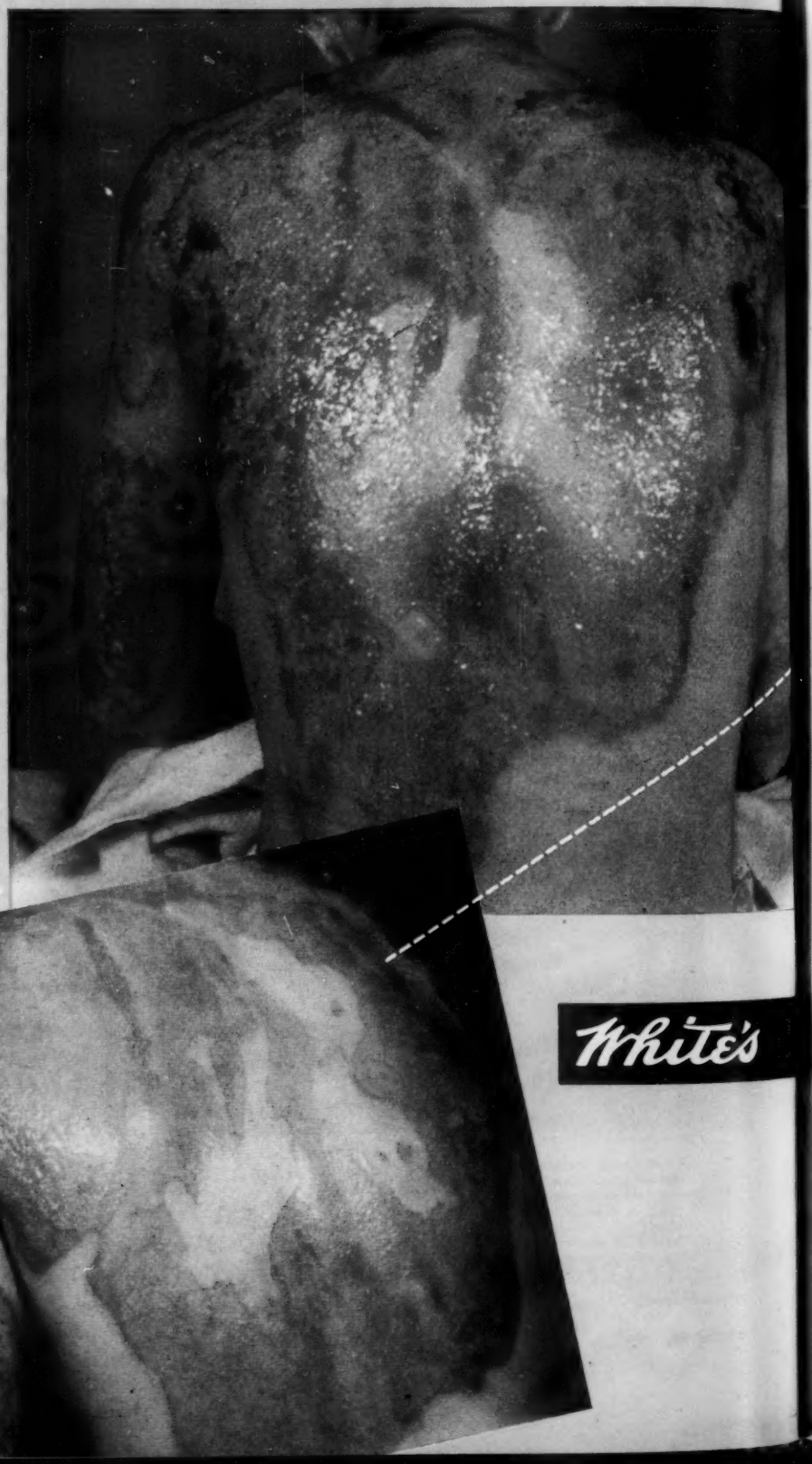

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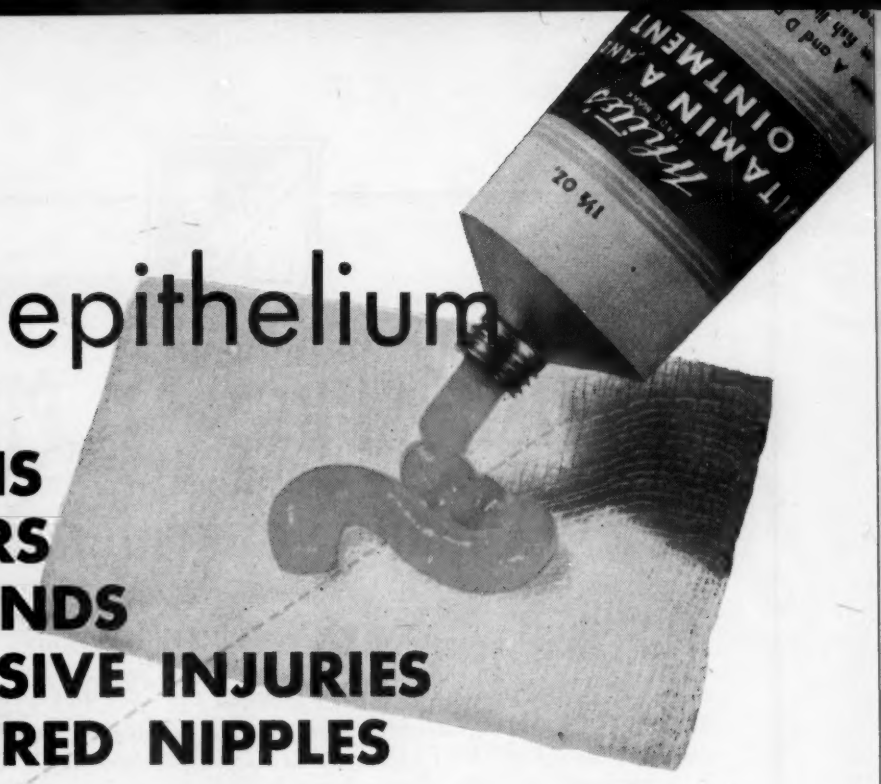

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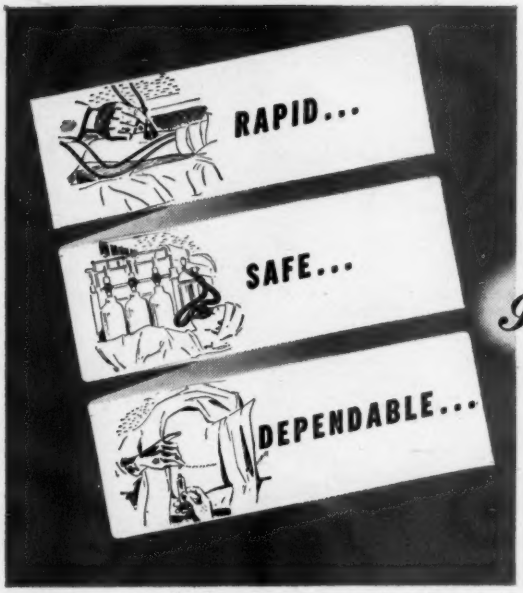

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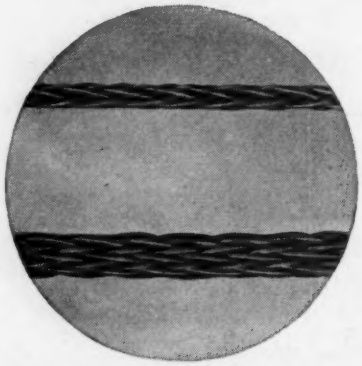

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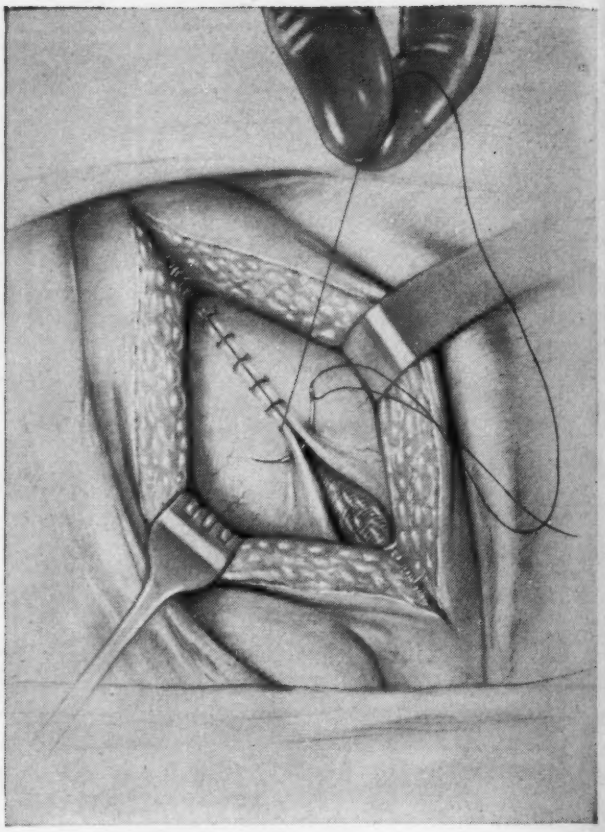

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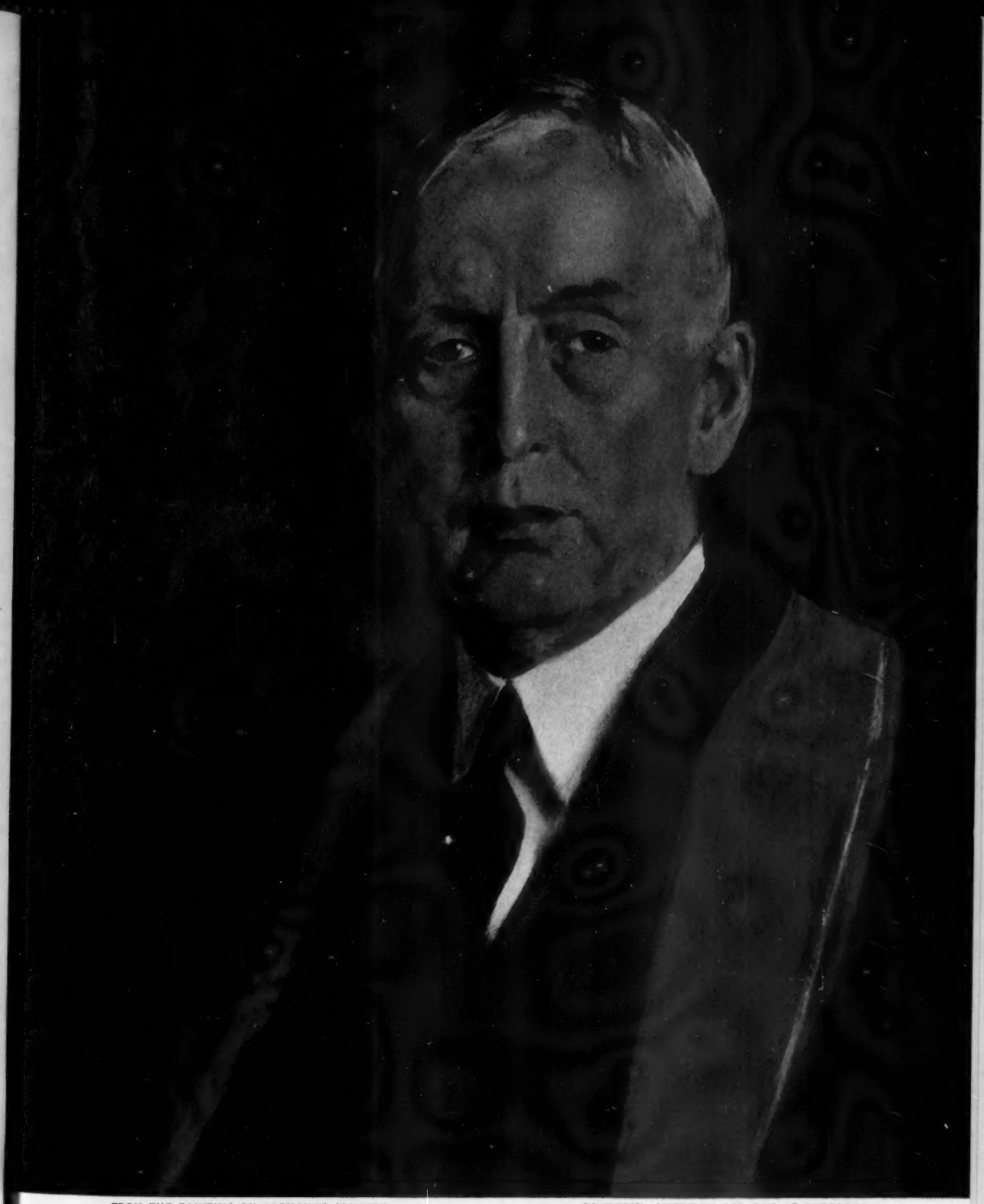

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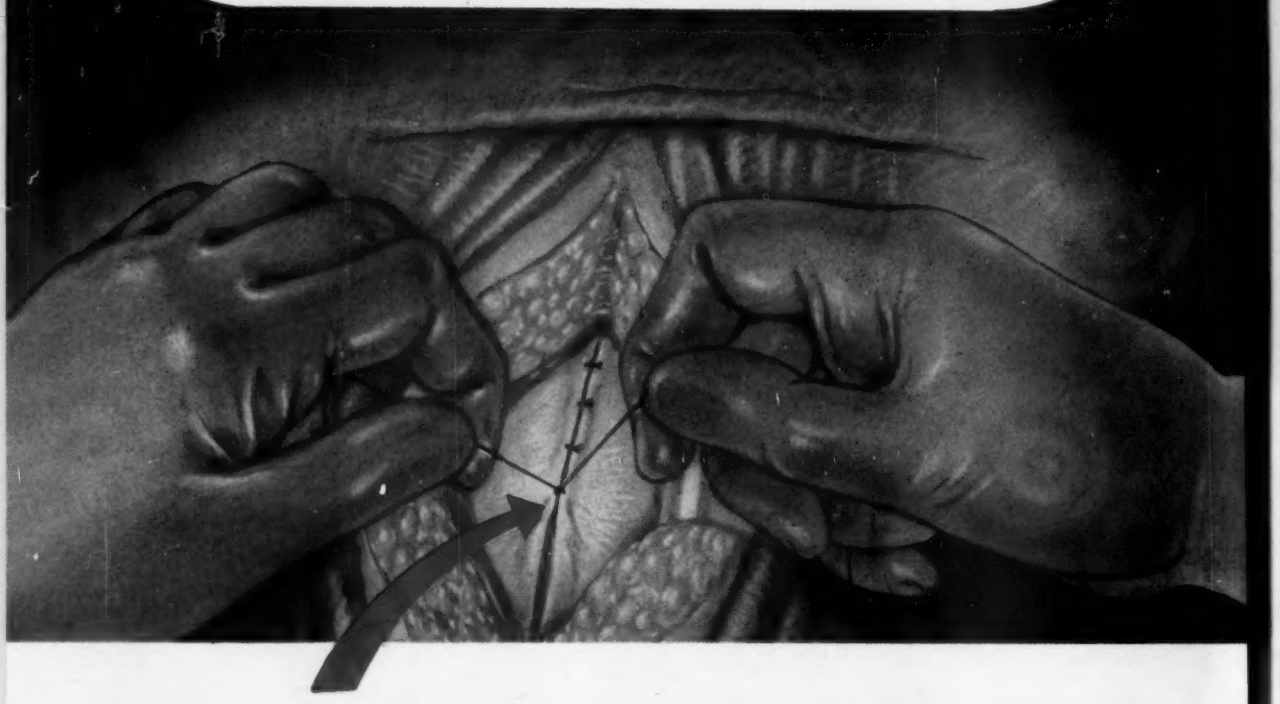

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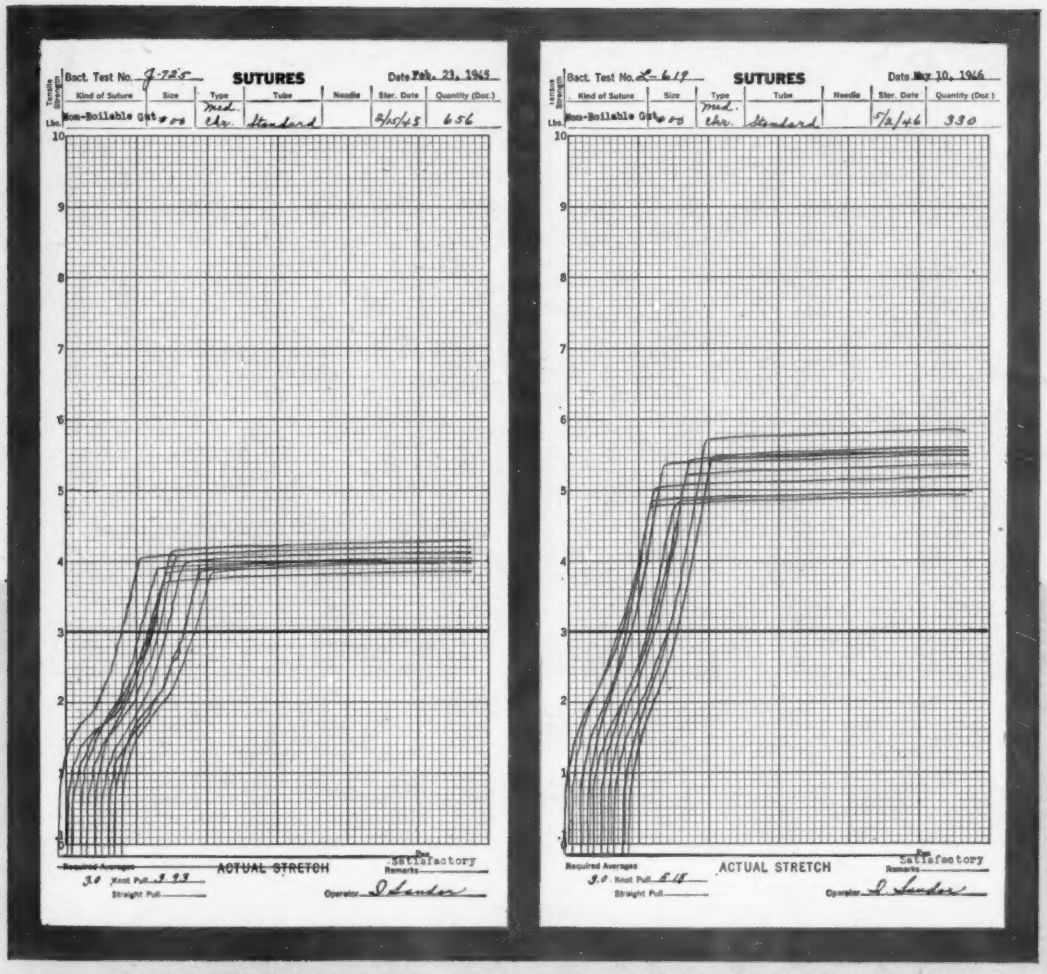

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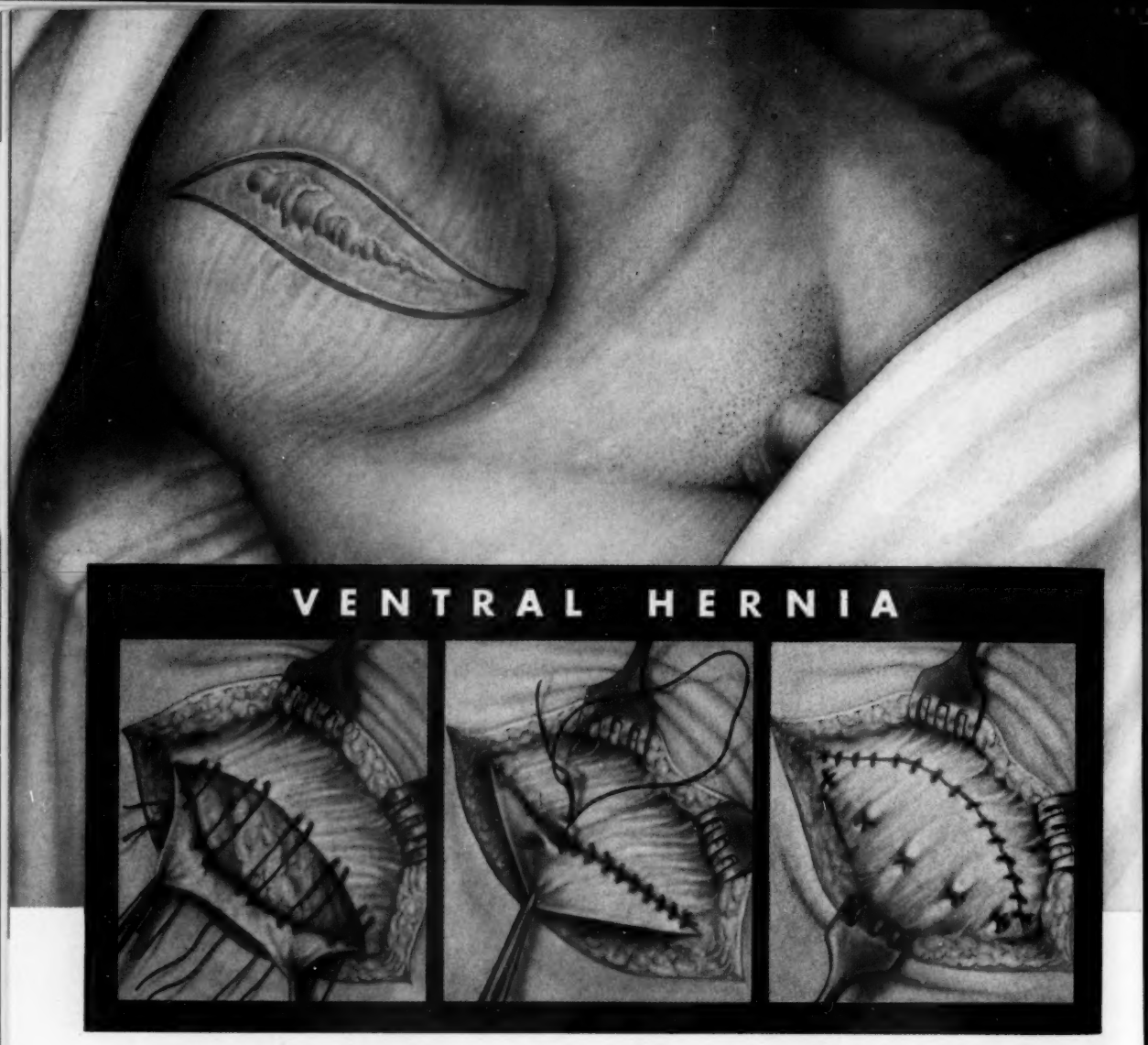

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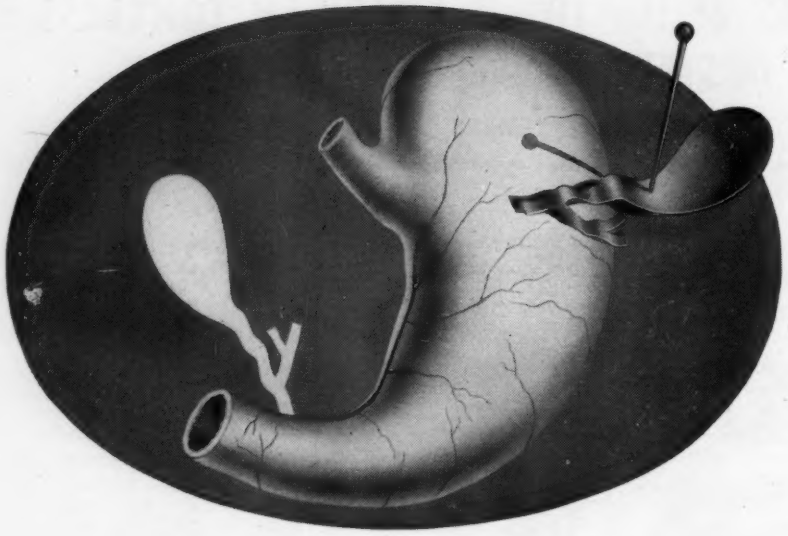

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Original Communications

SYMPATHECTOMY AS AN ADJUVANT IN THE OPERATIVE TREATMENT OF ANEURYSMS AND ARTERIOVENOUS FISTULAS

I. SYMPATHECTOMY PERFORMED BEFORE OR AT TIME OF OPERATION

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GAGE[1] and Bird[2] in 1934 independently utilized sympathetic interruption as a preliminary procedure before surgical extirpation of an aneurysm, the former by alcohol injection, the latter by ganglionectomy. Although impressed with the apparent benefit of sympathectomy in rendering the collateral circulation more efficient, Bird presented this contribution with definite reservations, being hopeful at that time that the recently introduced pavex boot might make unnecessary other efforts to foster development of collateral circulation. Gage, on the other hand, felt convinced that sympathetic interruption would maintain a prominent place in the surgical management of aneurysms. He and Ochsner subsequently reported additional successful experiences with this procedure.[3, 4] From time to time a number of other papers have appeared describing the use of sympathectomy before or at the time of operation for the cure of aneurysm.[5-12]

All of the relatively few cases thus far reported in the literature have been successful, what was considered adequate circulation following in each case an operation which had necessitated ligation of the affected artery. Because of this fact, I believe that one derives from these papers, perhaps contrary to the intent of their authors, the impression that sympathectomy is an almost impregnable defense against ischemic disaster in the treatment of vascular lesions requiring ligation of main arteries. My own experience certainly confirms the general usefulness of this procedure and yet makes evident certain limitations. It is the purpose of this communication to record a rather large experience with sympathectomy in cases of aneurysm and arteriovenous fistula, to point out its merits and its limitations, and to attempt to formulate a proper plan for its intelligent use as an adjuvant in the operative treatment of such

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cases. For the sake of simplicity, the problem will be divided into two parts. The use of sympathectomy before or at the time of operation for these lesions will be presented in this paper; the use of this procedure in an effort to correct certain circulatory difficulties following the operative cure of aneurysms and fistulas will be presented in another paper.[13]

There is ample experimental and clinical evidence to support the view that sympathectomy may be of definite help in maintaining the best possible circulation in various conditions in which the continuity of blood flow through important arterial trunks has been interrupted. Sympathectomy could conceivably be helpful in such cases by two mechanisms, the first of which is well established, whereas the second is hypothetical and requires considerable investigative support before it can be considered factual. In the first place, by eliminating vasoconstrictor impulses and contributing to the maintenance of near-maximal circulation, sympathectomy should ensure the fullest use of the existing collateral circulation. In the second place, as has been suggested, it might possibly aid in bringing about more rapid growth of new collateral channels through reduction in peripheral resistance to blood flow, or through some other means.

Indeed, one might readily defend the point of view that sympathectomy should be performed in every case in which there is an aneurysm or a fistula the cure of which might entail ligation of an important arterial stem. On the other hand, clinical experience has demonstrated that large numbers of aneurysms and fistulas can be extirpated without serious resultant ischemic difficulties, provided careful testing of the collateral circulation is used as a guide in the selection of the proper time for operation and provided the operation is carried out with extreme care so that no collateral vessels are needlessly sacrificed. Thus, some investigators have held that sympathectomy should be used almost uniformly in such cases; others have believed that one need rarely, if ever, resort to this procedure. In the cases on which the present study is based, it has been my practice to follow a course somewhat between these two views. Sympathectomy has been utilized whenever it might reasonably be expected to result in definite benefit to the patient. Undoubtedly the procedure has been used more often than was necessary, to prevent gangrene, for example. I have kept in mind, however, the fact that study of an extensive series of sympathectomies might permit a more rational evaluation of the procedure in the future, and I was convinced that if clear-cut benefit did not follow in every instance, at least no harm would result.

INDICATIONS FOR SYMPATHECTOMY AND CLINICAL MATERIAL

The chief indications which have been followed in selecting cases for sympathectomy were: (1) Evidence of poor collateral circulation in patients with lesions sufficiently old to have produced, under ordinary circumstances, a fairly efficient collateral circulation. (2) The coexistence of inadequate collateral circulation and of peripheral nerve injuries requiring surgical exploration. Since early surgical treatment of peripheral nerve injuries results in better return of function than late treatment of such lesions, it is my conviction

that every effort should be made to increase the efficiency of the collateral circulation to permit as early operation as possible. In such cases it is hazardous to explore a nerve before treatment of the aneurysm or fistula, and it is ordinarily feasible to carry out both procedures concomitantly. (3) The impossibility of testing the collateral circulation in certain cases in which an important arterial trunk appears to be involved. In occasional cases the affected artery cannot be compressed at the site of the fistula or aneurysm; hence, no accurate testing of the collateral circulation is possible. (4) The presence of ischemic lesions associated with aneurysm or fistula. (5) Intense vasospasm in the affected limb, or a rather severe generalized vasospastic disorder. (6) The loss of one or more major arteries by previous injury or operation in a limb in which the cure of an aneurysm or fistula will likely necessitate ligation of other important arterial channels. (7) Causalgia in the affected limb relieved temporarily but not cured by sympathetic blocks.

In the present series of cases,* 290 aneurysms and arteriovenous fistulas were operated upon. An additional 13 cases required no operative treatment because of "spontaneous cure" of the lesion by thrombosis. In this group of 303 cases, 78 sympathectomies were carried out before or at the time of operation. One additional sympathectomy should properly be included since it was performed in a patient thought to have an aneurysm, the signs of which were found subsequently to be due to costoclavicular compression of the subclavian vessels.[15] Of these 79 sympathectomies, 24 were dorsal and 55 lumbar sympathectomies. Lumbar sympathetic ganglionectomies were performed under spinal anesthesia through an anterior extraperitoneal muscle-splitting incision. The upper extremities were denervated by the preganglionic operation of Smithwick, performed under intratracheal gas-oxygen-ether anesthesia. No deaths and no serious complications occurred.

In Table I are summarized data concerning the distribution of cases according to the affected artery. Not included are two cases in which satisfactory "cure" of the lesion by thrombosis followed sympathectomy and the case mentioned previously in which the patient was found to have no aneurysm. It is

TABLE I. SYMPATHECTOMY PERFORMED BEFORE OR AT TIME OF OPERATION FOR ANEURYSM OR ARTERIOVENOUS FISTULA

	ARTERIAL ANEURYSM			ARTERIOVENOUS FISTULA		
SITE OF LESION	NO. OF PATIENTS OPERATED UPON	NO. OF PATIENTS SYMPATHECTOMIZED	PER CENT SYMPATHECTOMIZED	NO. OF PATIENTS OPERATED UPON	NO. OF PATIENTS SYMPATHECTOMIZED	PER CENT SYMPATHECTOMIZED
Innominate	1	1	100			
Subclavian	5	1	20	6	2	33.3
Axillary	13	7	53.8	12	4	33.3
Brachial	22	3	13.6	11	2	18.2
Common femoral				3	2	66.7
Femoral	6	3	50	47	14	29.8
Popliteal	16	12	75	41	13	31.7
Other	21	2	9.5	86	10	11.6
Total	84	29	34.5	206	47	22.6

*All but two were treated at the Mayo General Hospital;[14] the others were treated subsequently at the Johns Hopkins Hospital.

apparent from the data recorded that the majority of sympathectomies were carried out in patients with lesions of the larger peripheral arterial stems. Sympathectomy was performed in 25 of 57 cases of popliteal involvement (44 per cent), in 11 of 25 cases of axillary lesions (44 per cent), in 17 of 53 cases of femoral aneurysm or fistula (32.1 per cent), in 3 of 11 cases of subclavian (27.3 per cent), and in 5 of 33 cases of brachial lesions (15.1 per cent). A few sympathectomies were done in instances of involvement of the innominate or common femoral artery. In 12 of the 107 cases with involvement of vessels other than those just mentioned, sympathectomy was performed (11.2 per cent). As will be developed subsequently, a number of these latter cases were instances in which preoperative studies erroneously suggested involvement of an important artery near the affected vessel. Altogether 76 sympathectomies were performed in the 290 cases in which operative treatment of the aneurysm or fistula was necessary (26.2 per cent).

Sympathectomy was performed in a larger percentage of arterial aneurysms (34.5 per cent) than in cases of arteriovenous fistula (22.6 per cent). This difference is more apparent upon consideration of the axillary, femoral, and popliteal lesions, those for which sympathectomy was most frequently done. The percentage of arterial aneurysms in which sympathectomy was performed for these lesions was 53.8, 50, and 75, whereas the percentage of arteriovenous fistulas in which sympathectomy was carried out for these lesions was 33.3, 29.8, and 31.7. Although this difference is primarily a reflection of the tendency to poorer collateral circulation in instances of arterial aneurysm, it is partly dependent upon the fact that associated nerve injuries requiring operative treatment were twice as common in cases of arterial aneurysms as in those of arteriovenous fistula;[14] it is not due to a higher incidence of lesions of these major arterial stems in cases of arterial aneurysm. Forty-eight per cent of the arterial aneurysms operated upon involved the subclavian, axillary, femoral, and popliteal arteries; in 53 per cent of the arteriovenous fistulas there was involvement of these vessels.

RESULTS OF THE PROCEDURE

In Tables II to VIII are recorded data upon the patients who have had sympathectomy before or at the time of operation for aneurysm or fistula. An effort has been made to segregate them into groups according to the chief indication for the procedure. It should be pointed out that in certain instances sympathectomy was decided upon not because of a single reason but because of a combination of reasons. Such relevant data as are consistent with brevity are included in the tables.

SYMPATHECTOMY PERFORMED BECAUSE OF POOR COLLATERAL CIRCULATION

In Tables II and III are summarized data regarding 39 patients upon whom sympathectomy was performed because of poor collateral circulation. In these cases and in all others included in this study, the state of the collateral circulation was investigated by repeated use of a number of tests and observations, but chief reliance was placed upon the reactive hyperemia test of Matas. My

experience with these tests has been reported elsewhere.[16] To simplify interpretation of the results of sympathectomy, those cases in which the tests showed that the collateral circulation was satisfactory after sympathectomy are grouped in Table II; those in which the tests did not reveal adequate collateral circulation are placed in Table III.

In a number of these patients it will be seen that in addition to evidence of poor collateral circulation, there were other reasons why it was deemed advisable to make every effort to render the collateral circulation adequate as rapidly as possible. For example, in 16, or 41 per cent, there were present associated peripheral nerve lesions requiring operative treatment. In others there was severe pain or pronounced vasospasm and in one case there was superficial gangrene. In 34, or 87 per cent, the aneurysm or fistula was of three months' duration or longer before sympathectomy was performed, and in 18 of them (46 per cent) the lesion was of five months' duration or longer. In the five cases in which sympathectomy was performed earlier, specific indications were present which made it advisable, I felt, to proceed with sympathectomy without further delay. Two patients (Cases 6 and 18, Table II) had severe pain. In one of them a popliteal aneurysm had ruptured subcutaneously, and it was obvious that further increase in the size of the aneurysm might necessitate operation at any moment. In the other patient, in addition to severe causalgia, which was associated with a femoral arteriovenous fistula with saccular aneurysm and peroneal paralysis and which had necessitated the use of narcotics to the point of real danger of addiction, there was a compound comminuted fracture of the femur, intense vasospasm of the foot, an ulcer of the heel, and superficial gangrene of the toes. In both patients the pain was diminished or relieved and the tests for collateral circulation become adequate shortly after sympathectomy. A third patient (Case 20, Table II), with a popliteal fistula of two and one-half months' duration, had extremely poor collateral circulation and complete peroneal paralysis. The collateral circulation became adequate after sympathectomy, permitting early treatment of the aneurysm and the nerve lesion. The two other cases (Cases 3 and 4, Table III) were instances of a femoral and a popliteal aneurysm of two months' duration, in which the tests for collateral circulation were extremely poor. In neither case did these tests become satisfactory after operation, although they showed some improvement. In one patient "spontaneous cure" took place, and in the other operative treatment two months after sympathectomy was followed by an excellent result. In all of the patients some intermittent proximal occlusion of the involved artery had been practiced without apparent improvement in collateral circulation. In only a few, however, had this method been given a prolonged trial.

In Table II are grouped twenty-five patients in whom the previously poor results of testing the collateral circulation became satisfactory after sympathectomy. The interval between sympathectomy and operation upon the aneurysm or fistula did not necessarily correspond to the interval between sympathectomy and the time when these tests became adequate. Some of the patients were allowed to return home on sick leave between operations. In some the second operation was deferred because of an unrelated illness such as malaria

TABLE II. SYMPATHECTOMY PERFORMED BEFORE OPERATION FOR ANEURYSM OR FISTULA; INDICATION—POOR COLLATERAL CIRCULATION; CASES IN WHICH TESTS FOR COLLATERAL CIRCULATION BECAME SATISFACTORY AFTER SYMPATHECTOMY

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
			Cases of Arterial Aneurysm			
1	Axillary	3	2	E	Also had brachial plexus injury requiring neurolysis	Good; has some cold sensitivity
2	Brachial	5.5	5	E	Also plexus injury requiring lysis	Excellent
3	Brachial	5	2	E	Also median and ulnar palsy; median lysis, ulnar neurorrhaphy	Excellent
4	Brachial	3	10	A-E	Also plexus injury requiring lysis; tests for collateral circulation did not become satisfactory for 2 mo.	Excellent
5	Femoral	5.5	1	E		Excellent
6	Popliteal	2	3	A	Very large, subcutaneous rupture, severe pain, pain less after sympathectomy	Excellent
7	Popliteal	5	3	A		Excellent
8	Popliteal	5.5	5	A		Excellent
9	Popliteal	--	1.5	A	Arteriosclerotic aneurysm	Excellent
			Cases of Arteriovenous Fistula			
10	Subclavian	5	3	E	Also ulnar palsy, requiring lysis	Excellent
11	Axillary	3	2.5	E	Also plexus injury, lysis, radial neurorrhaphy, hand cold, blue before sympathectomy; circulation strikingly improved	Excellent
12	Axillary	5	3.5	E	Also plexus injury, requiring lysis	Excellent
13	Axillary	6.5	2	E		Excellent

or gastroenteritis. It is seen, however, that in most instances the operation upon the vascular lesion followed closely the sympathectomy. In 10, or 40 per cent, it was done within two weeks; in 17, or 68 per cent, in three weeks or less; and in 20, or 80 per cent, in four weeks or less. In only five instances was it delayed five weeks or more. In one of these (Case 18) the tests for collateral circulation became adequate shortly after sympathectomy, but operation was deferred because of a compound fracture of the femur and infected ulcers of the foot. In the other four cases the tests for collateral circulation showed steady improvement after sympathectomy.

It will be noted that 25 of the 39 patients (64 per cent) upon whom sympathectomy was performed because of inadequate circulation showed evidence of satisfactory collateral circulation after this procedure, and that in the majority of them these tests were adequate very shortly after operation. It will also be noted that there was no great difference in this respect between the group of arterial aneurysms and that of arteriovenous fistulas. Nine of 15 patients with arterial aneurysm (60 per cent) and 16 of 24 with fistulas (66.7

TABLE II. (CONT'D)

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
14	Axillary	6.5	3	E	Also plexus injury, ulnar and radial neurorrhaphy necessary	Excellent
15	Brachial	3	7.5	E	Also ulnar and median palsy requiring lysis, collateral circulation tests very poor before, good after sympathectomy	Excellent
16	Common femoral	5.5	1	E		Excellent
17	Femoral	3	2	E		Excellent
18	Femoral	2.5	21	E	Also peroneal palsy, F.C.C. femur and pain; tests for collateral circulation adequate shortly after sympathectomy; burning pain disappeared	Excellent
19	Femoral	3	4	E-R	Tests for collateral circulation improved progressively over period of several weeks after sympathectomy	Excellent; successful vein graft to arterial defect
20	Popliteal	2.5	2	E	Also peroneal palsy	Excellent
21	Popliteal	3.5	1.5	E	Also pronounced vasospasm	Excellent
22	Popliteal	3.5	2	E	Also peroneal palsy requiring suture	Excellent
23	Popliteal	4	3	E	Collateral circulation thought adequate after sympathectomy	Poor, gangrene of the distal third of the foot
24	Popliteal	10	3	E	Also peroneal palsy	Excellent
25	Popliteal	9	4	E-R		Excellent; continuity of artery maintained; ligation of fistula

Abbreviations used in this and the following tables:

E, Excision.

E-R, Excision with restoration or maintenance of continuity of affected artery.

A, Aneurysmororrhaphy or aneurysmotomy with intrasaccular ligation or transfixing of artery.

A-E, Aneurysmororrhaphy or similar procedure followed by excision of the sac.

A-E-R, Aneurysmororrhaphy or similar procedure followed by excision of the sac and by restoration of continuity of the artery.

per cent) showed evidence of good collateral circulation after sympathectomy, according to the reactive hyperemia test and other tests.

In all save two of the cases listed in Table II, cure of the aneurysm or fistula entailed ligation of the affected artery. In the exceptions (Cases 19 and 25), continuity of the artery was preserved or re-established by ligation of the fistula or by vein graft to bridge the arterial defect. In these and in the other tables where the result is said to be excellent, the limb maintained normal warmth and color under ordinary environmental conditions, no significant or

TABLE III. SYMPATHECTOMY PERFORMED BEFORE OPERATION FOR ANEURYSM OR FISTULA; INDICATION—POOR COLLATERAL CIRCULATION; CASES IN WHICH TEST FOR COLLATERAL CIRCULATION DID NOT BECOME SATISFACTORY AFTER SYMPATHECTOMY

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
			Cases of Arterial Aneurysm			
1	Axillary	3.5	9	A-E-R	Also plexus injury requiring lysis	Excellent; successful end-to-end suture
2	Brachial	4	6.5	A-E	Also plexus injury requiring lysis and radial neurorrhaphy	Excellent
3	Femoral	2		None	Thrombosis occurred after sympathectomy with gradual obliteration of sac	Excellent
4	Popliteal	2	8.5	A		Excellent
5	Popliteal	4	15	A		Excellent
6	Popliteal	--	17	E-R	Aneurysm due to medionecrosis; circulation in foot poor before, good after sympathectomy	Excellent; successful vein graft
			Cases of Arteriovenous Fistula			
7	Femoral	3.5	30	E-R	Collateral circulation improved after sympathectomy but never satisfactory	Excellent; continuity artery maintained, fistula ligated
8	Femoral	7	5	E-R	Collateral circulation tests improved markedly after sympathectomy became questionably adequate	Excellent; continuity artery maintained, fistula ligated
9	Femoral	5	9	E-R	Collateral circulation tests improved slightly but never became adequate	Excellent; continuity artery maintained, fistula ligated
10	Popliteal	3.5	10	E-R	Tests for collateral circulation improved markedly after sympathectomy; never entirely satisfactory	Excellent; continuity artery maintained, fistula ligated
11	Popliteal	6.5	10	E-R	Also peroneal palsy requiring suture; tests for collateral circulation improved but never became satisfactory.	Excellent; continuity artery maintained, fistula ligated
12	Popliteal	5	5	E-R	Tests for collateral circulation improved but never became completely satisfactory.	Excellent; continuity artery maintained, fistula ligated
13	Popliteal	11	3.5	E	Tests for collateral circulation improved but never became satisfactory	Excellent
14	Popliteal	5	13	E-R	Tests for collateral circulation improved slightly but never became satisfactory	Excellent; continuity artery maintained, fistula ligated

disturbing sensitivity to cold existed, and there was satisfactory evidence of return of nerve function. If follow-up of the patient was not continued long enough to permit restoration of sensation and motor power, at least other evidence, such as progression distally of the point at which Tinel's sign might be elicited, showed satisfactory improvement comparable to cases in which no vascular disorder existed. Naturally there was no regeneration of those nerves in which apparently irreparable damage had occurred and in which no reparative procedure could be carried out. Where speaking of an excellent result, I do not mean to imply that no fatigue on exercise was present, for this finding was invariably noted in cases in which such arteries as the femoral or popliteal had been ligated. One patient (Case 1) had some cold sensitivity following operation, in which it was necessary to ligate the axillary artery. In one instance gangrene occurred.

CASE REPORT

CASE 23 (Table II).—The patient was a 35-year-old soldier who had signs of popliteal arteriovenous fistula. There was no flush during the reactive hyperemia test. Four months after injury sympathectomy was performed. Immediately after this procedure the tests for collateral circulation showed definite improvement. The flush appeared promptly after deflation of the constricting cuff and steadily improved so that it was full and complete in two minutes, showing no further improvement upon release of pressure from the popliteal artery. Similar results were obtained on several occasions. The fistula was explored three weeks after sympathectomy. In addition to a large communication between the popliteal artery and vein there was also a small saccular aneurysm of the popliteal artery from which emerged a large geniculate branch. This branch had to be ligated in the excision of the lesion, and it appeared likely that the fistula had been occluded during the preoperative tests without interrupting blood flow through this branch, thus giving misleading information concerning the state of the collateral circulation.[16] The drapes were not applied in such a way as to keep the foot in view during the operative procedure, a precaution which is essential in every instance in which doubt exists of the adequacy of the collateral circulation. This precaution was unfortunately omitted as the result of a false sense of security which prevailed because up to this point no ischemic difficulty had occurred in a sympathectomized limb and there had been no experience to suggest that the reactive hyperemia test might giving misleading information. At the completion of operation the foot had poor color and warmth and within a few days gangrene was apparent, necessitating amputation of the distal third of the foot.

This case is cited in some detail because it illustrates the fact that sympathectomy offers no guarantee against ischemic disaster, because it shows the occasional fallibility of tests for collateral circulation, and because it makes obvious the necessity for every care and precaution. It is of interest that, with the exception of one case in which gangrene followed thrombosis which occurred on the sixth postoperative day in a limb which had previously shown excellent circulation, this is the only case in my experience of gangrene following surgical treatment of an aneurysm or fistula. This experience includes fifty-seven cases of femoral and fifty-seven cases of popliteal lesions cured by surgical means.

In Table III are summarized the fourteen cases in which sympathectomy failed to render the tests for collateral circulation satisfactory. In every instance there was some improvement in these tests after sympathetic interrup-

tion. In some, the tests became definitely better, but in none did they become adequate according to the standards which I feel should be followed as indicating reliably efficient collateral circulation.[16] It will be noted that in these cases a longer interval elapsed between sympathectomy and operation upon the aneurysm or fistula than in those cases listed in Table II. In only a single instance was this interval less than five weeks and in nine, or 64.3 per cent, it was two months or longer. It will also be seen that in one patient a satisfactory "cure" by thrombosis occurred, making operation unnecessary, and that in nine patients the continuity of the affected artery was maintained or restored by ligation of the fistula, by end-to-end suture, or by vein transplant. In only four, or 28.6 per cent, was it necessary to ligate the involved artery. In all cases an excellent result was obtained. The limbs maintained good color and warmth, and there was no sensitivity to cold; nerve return progressed satisfactorily when a peripheral nerve paralysis had been present. In those cases in which the continuity of blood flow through the affected artery was successfully maintained there was, in addition, no fatigue on exercise unless such fatigue had been present before operation.

In all cases the color and warmth of the affected hand or foot was observed during a prolonged period of precise occlusion of the artery with a rubber-shod clamp at the time of operation. In all instances save one, this period of observation showed that the collateral circulation was actually adequate, although repeated preoperative tests had led to a different interpretation. That the collateral circulation was efficient in at least the four instances in which the involved artery was ligated is evident from the postoperative result. In many of the cases some anatomic condition was found at the time of exploration which explained adequately the reason for the false results of the tests carried out before operation; for example, the presence of some large collateral vessels which would necessarily have been occluded during digital compression but which could be preserved at operation.[16] That the collateral circulation was apparently actually satisfactory in all save the one case referred to, and probably the one case in which operation was unnecessary, does not necessarily signify that it had been rendered so by sympathectomy. All that can be said is that the same tests for collateral circulation before and after sympathectomy showed some improvement in all instances after this procedure, and great improvement in some, but that they did not become completely satisfactory in any.

In Tables II and III, four types of response to sympathectomy occurred. In some cases the tests for collateral circulation became adequate immediately or shortly after sympathectomy. In some the tests showed significant improvement soon after sympathectomy, with slow, steady improvement until they became satisfactory some weeks later. In others the tests improved somewhat but never became adequate. In most of these, more precise tests performed with the lesion exposed at operation demonstrated that the collateral circulation actually was satisfactory, although in one instance such tests confirmed the inadequacy of the collateral circulation. It may be profitable to illustrate these four types of response with brief case reports.

CASE REPORTS

CASE 5 (Table II).—A 32-year-old soldier was injured by shell fragments on May 15, 1944, and was admitted to the Mayo General Hospital on September 1, with a large aneurysm in the region of the right femoral artery. There was no essential difference in color or temperature of the two feet. The reactive hyperemia test was carried out on several occasions between the date of admission and the latter part of October. No flush appeared in the foot during a period of three minutes, whereas a brilliant flush appeared immediately after release of pressure from the femoral artery. Lumbar sympathectomy was performed on October 31. The reactive hyperemia test was carried out for the first time on the third postoperative day. The flush was almost instantaneous, reached the toes in five seconds, was complete and full in sixty seconds, and showed no further improvement upon release of pressure from the femoral artery. Excision of the femoral aneurysm on November 6, with concomitant ligation of the femoral vein, was followed by an excellent result, the foot maintaining at all times good warmth and color.

CASE 19 (Table II).—A 26-year-old officer sustained an injury from a shell fragment on April 16, 1945, and was admitted to the Mayo General Hospital on May 29, with a mid-femoral arteriovenous fistula. There was no flush of the foot during the reactive hyperemia test. Sympathectomy was performed on July 14. When tested again one week later, a flush appeared in some of the toes in fifteen seconds and it became complete and of good quality in two minutes. However, there was a much more brilliant flush when pressure was released from the femoral artery. By August 17 the reactive hyperemia test showed an excellent flush which began in the toes in ten seconds and was complete and full in eighty seconds without improvement upon release of pressure from the femoral artery. On August 20 the fistula and the involved area of artery and vein were excised and a vein graft was utilized to bridge the arterial defect. The graft was successful and the patient had excellent circulation in the limb.

CASE 5 (Table III).—A 20-year-old soldier was injured on Dec. 10, 1944, and was admitted to the Mayo General Hospital on March 7, 1945, with a fairly large popliteal aneurysm. There was a poor and incomplete flush during the reactive hyperemia test on admission and during the next few weeks. On April 19 sympathectomy was performed. The results of the test steadily improved. For example, on May 3 a flush first reached the toes in thirty seconds. It improved slowly during the two-minute period of observation but became strikingly better upon release of pressure from the popliteal artery. By July 30 the flush reached the toes in ten seconds. Although it improved considerably during the two-minute period of observation, it improved still further upon release of pressure from the popliteal artery. The aneurysm was explored on August 3. The popliteal artery was occluded with a rubbershod clamp just proximal to the aneurysm. The foot maintained good color and warmth. The sac was opened and the artery transfixed above and below the defect. After operation the foot was always warm and well colored.

CASE 7 (Table III).—A 27-year-old soldier was injured on Feb. 26, 1945, and was admitted to the Mayo General Hospital on May 4, with signs of femoral arteriovenous fistula. No flush occurred during the reactive hyperemia test on admission or during the ensuing weeks. Finally, on June 5, sympathectomy was performed. There was only slight improvement after this procedure, the flush being of poor quality and incomplete in extent. During the following weeks there was no noticeable change. Thinking that some local factor might be responsible for the poor reactive hyperemia test and that the collateral circulation might actually be adequate, the lesion was cautiously explored on August 25. When a rubbershod clamp was placed upon the artery above and below the fistula, the foot became extremely pale and cool and remained so as long as the clamps were left in place. The wound was closed without any attempt to extirpate the fistula. The limb was tested repeatedly during the next few months. Finally, on January 11, the vessels were again explored. Once more precise occlusion of the artery caused persistent pallor and coldness of the foot. The

fistula was carefully dissected out, and it became evident that it could be transfixed and reinforced by a segment of the divided vein with preservation of the continuity of the artery. This was done with excellent result.

TABLE IV. SYMPATHECTOMY PERFORMED BEFORE OPERATION FOR ANEURYSM OR FISTULA; INDICATION—IMPOSSIBILITY OF TESTING THE COLLATERAL CIRCULATION

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
			Cases of Arterial Aneurysm			
1	Innominate	9	8	Triple ligation	At previous exploration hand became completely pallied with innominate occlusion; partial proximal ligation had failed as judged by oscillometry, etc.	Excellent
2	Subclavian	4.5	2	A-E	Also plexus injury requiring lysis	Excellent
3	Axillary	3.5	7	A-E	Also plexus injury requiring lysis; also cold sensitivity	Good; cold sensitivity
4	Axillary	3	2	A-E	Also plexus injury requiring lysis	Excellent
5	Femoral	1.5	2.5	A	Huge aneurysm, edema, coldness of foot, pain; circulation and pain improved after sympathectomy	Excellent
6	Popliteal	2	1	A	Huge infected aneurysm, loss anterior tibial group muscles, large ulcer; aneurysm ruptured subcutaneously 5 days after sympathectomy, forcing operation	Excellent
			Cases of Arteriovenous Fistula			
7	Aorta-innominate-subclavian	5.5	10	Exploration	Thought before exploration to involve innominate vessels	--------
8	Subclavian	8.5	2	E	An intramediastinal fistula	Excellent
9	? Subclavian	4.5	2	Exploration	Continuous bruit and thrill disappeared after sympathectomy; slight systolic bruit remained	Excellent; thrombosis of fistula
10	Brachial	2	1	E	Huge A-V saccular aneurysm, pain and swelling prohibited testing collateral; severe plexus injury requiring lysis and suture, circulation of hand impaired, cold sensitivity; rupture 5 days after sympathectomy forced operation	Good; slight cold sensitivity

SYMPATHECTOMY PERFORMED BECAUSE OF IMPOSSIBILITY OF TESTING THE COLLATERAL CIRCULATION

Table IV summarizes data concerning ten patients in whom sympathectomy was performed because it was impossible to compress the involved artery at the site of the aneurysm or fistula, and consequently to test the state of

the collateral circulation. In three cases the artery could not be compressed near the affected portion because of the very large size of the aneurysm and the great pain associated with it. In four cases the lesion was within the mediastinum. In the other three cases, axillary or subclavian lesions were so covered by the clavicle and the heavy musculature that the artery could not be occluded near the site of the defect. Since in these cases, with one exception, there is no way in which one can tell what the result might have been had sympathectomy not been performed, it is difficult to evaluate the effect of this procedure. Certain data are suggestive, however, that sympathectomy was beneficial. In the first place, in the exceptional case mentioned previously (Case 1) complete pallor had occurred during temporary occlusion of the innominate artery proximal to the aneurysm during an exploratory mediastinotomy. A partial proximal ligation was done, but the resulting reduction in pulsation and oscillometry in the extremity was so transient that it was obvious that the proximal ligature was a failure. Complete proximal and distal ligation after sympathectomy resulted in cure of the aneurysm and the maintenance of excellent circulation in the hand. In two patients (Cases 3 and 10) some sensitivity to cold was present after operation. Judging from the beneficial effects of sympathectomy in improving or relieving cold sensitivity following ligation of arteries for the cure of aneurysm or fistula,[13] there is every reason to suppose that these patients would have had more annoying sensitivity to cold had sympathectomy not been performed. Two patients (Cases 5 and 10) who had severe pain were more comfortable after sympathectomy than before. In the four patients (Cases 2, 3, 4, and 10) in whom there was extensive damage to the brachial plexus, return of nerve function has been as good as could reasonably be expected considering the state of the nerves at the time of exploration. In one patient (Case 9) signs of a mediastinal subclavian fistula disappeared after sympathectomy. The possible role of sympathetic denervation in bringing about "cure" through thrombosis will be discussed subsequently. Obviously the sympathectomy performed in Case 7 in which the vascular lesion was afterward found inoperable was seen in retrospect to have been needless.

SYMPATHECTOMY PERFORMED BECAUSE OF VASOSPASM

In Table V are recorded data upon six patients in whom sympathectomy was performed primarily because of vasospasm. In three of them there was evidence of intense persistent vasospasm in the affected limb. In the other three patients there was, in addition, a long-standing history of a pronounced tendency to vasospasm in all the extremities. Since maintenance of adequate circulation would depend upon full utilization of the existing collateral vessels should operative cure necessitate ligation of the affected main artery, it is important that this circulation not be compromised by persistent vasoconstriction. The only means of being certain that such vasoconstriction will not jeopardize the circulation is by interruption of the sympathetic innervation. The results in these cases, and in a number of others listed in other tables in which definite vasospasm was present, suggest that sympathectomy yields excellent results in such cases. In all of them the hand or foot remained warm and well

TABLE V. SYMPATHECTOMY PERFORMED BEFORE OPERATION FOR ANEURYSM OR FISTULA; INDICATION—VASOSPASM

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
			Cases of Arterial Aneurysm			
1	Femoral	3.5	2	E	Mid-foot amputation had been done for trauma; large ulcer, rapid healing after sympathectomy	Excellent; healed, case suitable for Syme amputation
			Cases of Arteriovenous Fistula			
2	Femoral	7	4.5	E	Long history of vasospasm; tests for collateral circulation only fair before, good after sympathectomy	Excellent
3	Femoral	3	7	E	Long history Raynaud-like disorder	Excellent
4	Popliteal	2.5	7	E	Marked vasospasm for years; tests for collateral circulation only fair before sympathectomy	Excellent
5	Popliteal	3	1	E	Affected foot remained cold in ordinary room temperature, other warm; ulcer of leg	Excellent
6	Foot, cirsoid		4	E	Cyanosis and coldness of foot had followed excision of posterior tibial A-V; two A-Vs remained to be excised, involving peroneal and anterior tibial vessels, one excised at time of sympathectomy, other 4 weeks later; cyanosis and coldness disappeared after sympathectomy	Good; only difficulty was slow healing of ulcer of foot

colored after operative cure of the aneurysm or fistula. In several of the patients in whom tests for collateral circulation were only fair before sympathectomy, these tests became good following the procedure.

SYMPATHECTOMY PERFORMED BECAUSE OF CAUSALGIA, ISCHEMIC LESIONS, AND OTHER CONDITIONS

Table VI includes seven patients for whom sympathectomy was performed because of various indications. In two (Cases 2 and 3) the procedure was carried out chiefly because of causalgia. Prompt and complete relief occurred in Case 2; in Case 3 the patient felt "about 90 per cent" relieved and was rapidly deprived of narcotics, to the use of which he had become almost addicted. This patient also had other complications such as a nerve paralysis, a compound fracture, ulcers, and gangrene. All healed and adequate circulation was maintained. In one other patient (Case 4) all of the toes were gangrenous and infected, the metatarsals were badly shattered, the entire foot was extensively

TABLE VI. SYMPATHECTOMY PERFORMED BEFORE OPERATION FOR ANEURYSM OR FISTULA; MISCELLANEOUS INDICATIONS

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
			Cases of Arterial Aneurysm			
1	Axillary	8	2	E	Impaired circulation; extensive plexus injury requiring lysis and radial suture	Excellent
2	Axillary	2	12	E	Causalgia; relief after sympathectomy	Excellent
			Cases of Arteriovenous Fistula			
3	Femoral	1	14	E	Causalgia, superficial gangrene of toe and heel, peroneal palsy, F.C.C. femur; pain relieved, ulcers healed slowly after sympathectomy	Excellent
4	Femoral	2	16	E	Gangrene of toes, multiple fractures of metacarpals, compounded and infected F.C.C. femur; healing after sympathectomy and amputation of toes; fractures healed, infection cleared	Excellent
5	Femoral	5	2.5	E	Impaired circulation and complete sciatic paralysis; nerve suture had been done, ulcer of foot	Good; ulcer healed, some cold sensitivity
6	Popliteal	2	7	E	Peroneal paralysis; collateral circulation only fair before sympathectomy	Excellent
7	Ulnar cirsoid		1	E	Had 3 previous operations with ligation of radial and ulnar arteries and a median palsy; impossible to foretell what collaterals might have to be sacrificed in a radical excision	Excellent

infected, and there was a compound comminuted fracture of the femur. The gangrenous toes were amputed at the time of sympathectomy. The end result was cure of the fistula, healing of the fractures, clearing of the infection, and a useful limb with excellent circulation. Three patients (Cases 1, 5, and 6) had peripheral nerve lesions in limbs in which the circulation was obviously impaired or in which the collateral circulation was judged to be only questionably adequate. In addition, one had an ulcer of the foot. The remaining patient (Case 7) was one in whom three previous attempts by other surgeons had failed to effect a cure and in whom both the ulnar and radial arteries had been ligated and divided. It seemed likely that important collateral vessels might have to be sacrificed in a radical excision of the cirsoid aneurysm which involved the ulnar side of the forearm, and it was felt that sympathectomy might offer worth-while protection against ischemic difficulties. Operative cure necessitated excision of the flexor sublimis muscle and the extensive vascular channels in and about this muscle. Circulation in the hand remained excellent.

SYMPATHECTOMY PERFORMED NEEDLESSLY BECAUSE OF ERROR IN LOCALIZING THE LESION

In Table VII are summarized seven cases in which sympathectomy was performed because an aneurysm or fistula was thought preoperatively to involve arteries other than those actually affected and in which tests, as well as they could be carried out, indicated poor collateral circulation. In three cases (Cases 1, 2, and 3 digital pressure sufficient to still the aneurysm or fistula invariably occluded the overlying femoral as well as the involved profunda femoral artery. In all of them it was thought, consequently, that the lesion was of the femoral or common femoral artery. In Cases 4 and 5 the fistula was in such close proximity to the popliteal artery that the bruit and thrill could be eliminated only by digital pressure which compressed the adjacent popliteal artery. In

TABLE VII. SYMPATHECTOMY PERFORMED BEFORE OPERATION FOR ANEURYSM OR FISTULA; CASES IN WHICH A MISTAKE IN LOCALIZATION OF THE LESIONS WAS MADE

CASE NO.	PREOPERATIVE LOCALIZATION	ACTUAL LOCATION OF LESION	INTERVAL BETWEEN INJURY AND SYMPATHECTOMY (IN MO.)	INTERVAL BETWEEN SYMPATHECTOMY AND OPERATION (IN WEEKS)	TYPE OF OPERATION	COMMENT	RESULT
Cases of Arterial Aneurysm							
1	Femoral	Profunda	3	10	A	Compression which stilled aneurysm obliterated femoral pulse; thrombosis and shrinkage occurred after sympathectomy but sac persisted	Excellent
Cases of Arteriovenous Fistula							
2	Common femoral	Profunda	28	10	E	Compression which eliminated bruit and thrill stopped femoral pulse	Excellent
3	Femoral	Profunda	6	8	E	Compression which eliminated bruit and thrill stopped femoral pulse	Excellent
4	Popliteal	Geniculate	8	6	E	Bruit and thrill could not be eliminated by pressure without loss of popliteal pulse	Excellent
5	Popliteal	Posterior tibial	5	6	E	A very high posterior tibial lesion; bruit and thrill could not be eliminated by pressure without loss of posterior and anterior tibial pulse	Excellent
6	Subclavian	Transverse cervical	4.5	3	E	Bruit and thrill could not be stopped by pressure without loss of brachial pulse	Excellent
7	Posterior and anterior tibial	Posterior tibial	3.5	4	E	Bruit and thrill could be stopped only by pressure, which caused loss of anterior and posterior tibial pulses; had tibial paralysis and F.C.C. fibula	Excellent

Case 6 a fistula between the transverse cervical artery and the internal jugular vein could be occluded only by pressure which obliterated the brachial pulse and was thought to involve the subclavian vessels. In the remaining case, an instance of a posterior tibial fistula, it was feared that the anterior tibial vessels might also be involved since the fistula could be closed only by compression which occluded the anterior as well as the posterior tibial artery. Perhaps the extensive fracture of the fibula contributed to the difficulty of accurate digital compression. In all cases, tests for collateral circulation were poor before and good after sympathectomy. It is apparent in retrospect that had correct localization been possible, sympathectomy could have been safely omitted. It is also apparent in retrospect that in all cases except possibly Case 4, arteriograms might have established the correct location of the lesion.

SYMPATHECTOMY PERFORMED AT TIME OF OPERATION UPON ANEURYSM OR FISTULA

In nine instances sympathectomy and operative attack upon the aneurysm or fistula were performed at the same session. The cases are summarized in Table VIII. In one patient (Case 9) sympathectomy was carried out primarily because the sympathetic chain was easily exposed in the operative incision through which the iliac artery had been isolated as a preliminary safeguard. The fistula was so high that it was thought to involve the common femoral vessels. Actually, there was a fistula between the medial circumflex femoral artery and the common femoral vein. In another instance (Case 5) sympathectomy might also have been omitted had the fistula been correctly localized before exploration. This patient had a very large aneurysm in the anterior aspect of the thigh which could be stilled only by pressure which occluded the femoral artery. The profunda had been previously ligated, shortly after injury. Tests for collateral circulation were extremely poor before, and excellent after, sympathectomy. In reality the aneurysm involved only the lateral femoral circumflex artery. The results were excellent in all cases but two. In one (Case 7), although the foot at all times after operation was warm and well colored, some peroneal sensory loss without motor involvement was added to the pre-existing tibial and saphenous anesthesia. Because at no time was there evidence of circulatory impairment it seems more likely that this complication was due to pressure from the tourniquet than to postoperative ischemia. In the other patient (Case 3) ischemic paralysis developed after operation, from which he fortunately made a complete recovery. The circulation was obviously impaired for a few hours after operation, although the limb rapidly regained and maintained normal warmth and color. This was a case in which sympathectomy and operation upon the vascular lesion were performed concomitantly without retesting the collateral circulation following sympathectomy—an omission which we have learned to avoid. That it is sometimes advantageous to do both operations at one sitting is obvious from consideration of those cases in which severe pain was present. In Case 2, for example, a very large popliteal aneurysm, which had ruptured subcutaneously, was so painful that the patient was writhing in agony and large doses of morphine were ineffective in affording relief. The reactive hyperemia test was characterized by complete absence of

TABLE VIII. SYMPATHECTOMY PERFORMED AT THE TIME OF OPERATION FOR ANEURYSM OF FISTULA

NO. CASE	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND OPERATION (IN MO.)	TYPE OF OPERATION	COMMENT	RESULT
			Cases of Arterial Aneurysm		
1	Popliteal	3	A	Infected, subcutaneously ruptured aneurysm with severe pain	Excellent
2	Popliteal	3	A	Huge, subcutaneously ruptured aneurysm with severe pain; reactive hyperemia test nil before sympathectomy, complete flush in 30 seconds after sympathectomy	Excellent
3	Popliteal	6	E	Following excision of aneurysm, foot cold and blue; circulation still impaired after sympathectomy, but foot warm and pink few hours later	Ischemic palsy developed; recovery
4	Popliteal	4	A	Large, infected mycotic aneurysm with sensory and motor loss in foot and much pain; reactive hyperemia test excellent after sympathectomy	Excellent; steady improvement in ischemic palsy
5	Lateral femoral circumflex	11	A	Profunda had been ligated at time of injury; aneurysm could be stilled only by pressure which stopped femoral pulse, reactive hyperemia test nil before sympathectomy, good flush 30 seconds after sympathectomy	Excellent
			Cases of Arteriovenous Fistula		
6	Common femoral	4.5	E	Tests for collateral circulation poor before operation	Excellent
7	Femoral	3	E	Huge, painful subcutaneously ruptured aneurysm, tibial and saphenous sensory loss; previously poor tests for collateral circulation became good after sympathectomy	Foot remained warm, well colored; some peroneal sensory loss, perhaps due to tourniquet
8	Hypogastric	5	E	External iliac fistula on same side had been excised 7 weeks after injury; tests for collateral circulation poor before, good after, sympathectomy	Excellent
9	Medical circumflex femoral	13	E	A-V caused by surgical ligation of the femoral artery at time of injury; bruit and thrill could be stopped only by high pressure in femoral area, iliac arteries explored as precautionary measure, sympathectomy done only because chain lay exposed during procedure	Excellent

flush. Following sympathectomy a complete and intense flush was present within thirty seconds after release of the constricting cuff. Aneurysmorrhaphy was promptly done. The patient was entirely comfortable after operation and the foot had excellent circulation.

EFFECT OF SYMPATHECTOMY UPON EXERCISE TOLERANCE AND COLD SENSITIVITY

There remains to be considered the influence of sympathectomy upon the two commonest functional disorders which follow the ligation of arteries for

the cure of aneurysms and fistulas, namely, decrease in exercise tolerance and sensitivity of the limb to cold. In regard to the effect of sympathectomy upon intermittent claudication or its equivalent, it will be best to consider only those vascular lesions involving the popliteal, femoral, and common femoral arteries since reduction in exercise tolerance is particularly noticeable after ligation of these vessels. It is necessary to eliminate those cases in which walking was made difficult because of associated fractures, amputation, or motor loss from peripheral nerve injury. It is also necessary to exclude those few cases in which the walking distance was apparently significantly reduced before operation, at a time when the continuity of blood flow through the affected artery was uninterrupted. In addition, those cases must be excluded in which it was possible to preserve the continuity of the artery at the time of operation. Exercise tolerance was determined by having the patient walk at normal pace with a pedometer or over a measured course until he was forced to stop because of fatigue or, more rarely, cramps in the limb. The distance was approximately the same in the two groups. Those whose operation had necessitated ligation of the popliteal artery were forced to stop after walking an average of 0.68 miles in the group who had not undergone sympathectomy, 0.73 miles in the other group. The distance was the same, an average of 0.73 miles, in the sympathectomized and control groups of patients whose operation had necessitated ligation of the femoral or common femoral artery.

These data demonstrate that exercise tolerance was almost precisely the same regardless of whether sympathectomy had been performed. Unfortunately, the two groups are not carefully controlled from several important standpoints. The interval between operation and final testing of walking distance varied from patient to patient. Consideration of this factor is, furthermore, futile because some patients rapidly reached their apparent maximal exercise tolerance whereas others noted slow and more prolonged improvement in the distance they could walk. In addition, one cannot analyze properly the possible exaggeration of this symptom on the part of some patients in a desire to avoid duty and to be separated from the service. Finally, the two groups are not entirely comparable in that there was evidence from various tests and observations that the collateral circulation was more efficient in the group in which sympathectomy was considered unnecessary.

In regard to the effect of sympathectomy in preventing sensitivity of the limb to cold, analysis of the cases gives more clear-cut information. Sensitivity to cold of varying degree followed operation upon the subclavian, axillary, and brachial arteries in which ligation was necessary or reparative procedures failed to maintain continuity of the vessel in 5 of 18 patients (27.2 per cent) in whom sympathectomy was performed before or at the time I operated and in only one of 32 cases (3.1 per cent) of popliteal, femoral, or common femoral lesions treated similarly. Of these 6 patients, cold sensitivity was present before operation in 2. On the other hand, cold sensitivity was present after operation in 13 of 42 (31 per cent) patients treated for lesions of the subclavian, axillary, and brachial vessels without sympathectomy, and in 5 of the 65 (7.7 per cent) cases with popliteal, femoral, or common femoral lesions. Eight of

these 18 patients had some cold sensitivity before operation. Among those patients operated upon elsewhere, sensitivity to cold was present in 5 of 11 (45.5 per cent) with aneurysms or fistulas of the main arteries to the upper extremity, and in 9 of 30 (30 per cent) with lesions of the main arteries of the lower extremities. The single patient who had been sympathectomized at the time of operation had no cold sensitivity. Altogether 13.7 per cent of those 51 patients sympathectomized before operation upon the vascular lesions under consideration had sensitivity of the limb to cold and 21.6 per cent of those 148 patients who did not undergo sympathectomy.

EFFECT OF SYMPATHECTOMY UPON INTRASACCULAR THROMBOSIS

Not uncommonly sympathectomy was followed by a noticeable increase in the mural thrombus within the aneurysmal sac. Sometimes this process was very extensive. For example, in one patient (Case 1, Table VII) a large pulsating aneurysm in the thigh became, after sympathectomy, progressively smaller and firmer and eventually lost its pulsation. Indeed, clinically, it appeared that the sac had been obliterated. Arteriograms, however, revealed the persistence of a sac several centimeters in diameter. At operation the laminated mural thrombus was many times larger than the remaining aneurysmal cavity. In two instances apparent cures occurred. In one (Case 9, Table IV) there were signs suggestive of an arteriovenous fistula of the proximal portion of the left subclavian vessels. After sympathectomy the thrill and continuous bruit disappeared and only a short systolic bruit remained. In the belief that a saccular aneurysm remained, the extramediastinal portions of the vessels were explored. No aneurysm was encountered, and there was such dense scarring about the vessels as one approached the mediastinum that exploration was discontinued on the assumption that the remaining systolic bruit was probably the result of partial compression of the artery by scar tissue. The other patient (Case 3, Table III) had a pulsating femoral aneurysm about 7 cm. in diameter, and evidence of completely inadequate collateral circulation. Sympathectomy was performed two months after injury. After this procedure, the aneurysm became steadily a little firmer and smaller and pulsated less vigorously. This process was slow during the first few months but finally, six months after sympathectomy, only a small, firm nonexpansile mass remained. Arteriograms revealed almost complete obliteration of the sac. During the ensuing few weeks the mass practically disappeared and it was evident that a satisfactory "cure" had been obtained.

It must be pointed out that "spontaneous cure" occurs occasionally without sympathectomy in cases of both arterial aneurysm and arteriovenous fistula. Indeed, this occurred in 11 of 225 cases studied, an incidence of 4.9 per cent. On the other hand, a "cure" by thrombosis occurred in only 2 of 78 patients sympathectomized, an incidence of 2.6 per cent. It is, therefore, difficult to be certain that the thrombosis is actually the result of the sympathectomy. This is particularly true when complete thrombosis occurs gradually and over a long period of time as in Case 3, Table III. When it occurs promptly after sympathectomy, as in some of the cases recorded in the literature, the march of

events would suggest that this process has resulted from sympathectomy. This seems all the more likely because of incomplete thrombosis of the sac which is commonly observed after sympathetic denervation. Gage suggested that the responsible mechanism was the decrease in peripheral resistance. I know of no better hypothesis.

The question arises whether the increase in mural thrombus or the complete thrombosis of the sac can be associated with extension distally of the clot. The course of one patient (Case 9, Table II) suggests that, rare as it may be, this occurrence may take place. The patient was a 49-year-old man with an arteriosclerotic aneurysm of the popliteal artery. On admission to the hospital there was a right popliteal aneurysm which pulsated vigorously and had a loud systolic bruit. There was evidence of peripheral arteriosclerosis. The right dorsal pedal pulse was present, the posterior tibial absent; both were present in the left foot. Collateral circulation was very poor. These findings were checked the day before sympathectomy, but unfortunately the pulses were not palpated and oscillometric studies were not made immediately before sympathectomy. The day after sympathectomy the aneurysm was noted to be somewhat firmer and to have only a faint shocklike sound in place of the systolic bruit. The dorsal pedal pulse had disappeared and oscillometric studies confirmed the impression that the popliteal artery was occluded distal to the aneurysm. This, as well as the recent increase in the extent of mural thrombus, was substantiated at operation eight days later. Although there is no proof in this case, the evidence suggests that the extension of the mural thrombus following sympathectomy brought about occlusion of the artery distal to the aneurysm. An excellent result followed aneurysmorrhaphy.

DISCUSSION

In considering the role of sympathectomy in the operative treatment of aneurysms and arteriovenous fistulas, it is important to keep in mind that, in the hands of those familiar with it, this procedure is associated with very little discomfort and minimal risk. Patients can be ambulatory the day after either dorsal or lumbar sympathectomy. In my own experience there have been no deaths and complications have been extremely rare. In these cases I have preferred abolishing vasoconstrictor impulses by operative sympathectomy rather than by injection of alcohol, for two reasons: permanence of the sympathetic denervation, and absence of the neuritic pains which sometimes are a distressing sequel of alcohol injection.

The series of cases presented gives convincing evidence of the usefulness of sympathectomy in rendering the collateral circulation more efficient by elimination of vasoconstriction in the collateral vessels. This is exemplified by the almost universal maintenance of excellent warmth and color in the sympathectomized hand or foot in cases in which cure of the vascular lesion had entailed arterial ligation, and more particularly by the striking improvement in the tests for collateral circulation which so often occurs immediately after sympathectomy has been carried out. I do not feel that these data offered convincing proof that sympathectomy actually increases the collateral circulation by foster-

ing growth of new collateral channels. Certainly those cases in which the collateral circulation shows only slight improvement immediately after sympathectomy but steady significant improvement during ensuing weeks and months, would suggest that sympathectomy may have this effect. It must be pointed out, however, that a number of cases have been observed in which, without any effort to increase the collateral circulation, the formerly poor tests have shown a remarkable improvement during a short period of observation. Consequently, it is my feeling that the observations cited are somewhat suggestive but certainly offer no proof that sympathectomy actually promotes the growth of new collaterals.

The immediate effect of sympathectomy upon the state of collateral circulation can be predicted with reasonable accuracy by comparing the results of the reactive hyperemia test in any given patient under ordinary environmental conditions and those obtained during reflex vasodilatation, or anesthesia, or better still, during procaine sympathetic block. I think, however, that such studies are unnecessary as a routine measure and that one can proceed with sympathectomy where the indications are plain. Should tests for collateral circulation during such preoperative studies show a distinct improvement, one would have only additional confirmation of the advisability of sympathectomy. Should these tests show no improvement the state of the circulation would be sufficiently precarious to warrant the use of any reasonably safe procedure to add some safeguard against ischemic difficulties.

The results of sympathectomy and a rational outline for its use in cases of aneurysm or fistula can best be evaluated by a brief review of the various indications for its use. In the first place, it seems advisable to employ the procedure in cases where there is evidence of poor collateral circulation, in which the lesions are of sufficient duration to have ordinarily produced good collateral circulation, and in which simpler means of improving the collateral circulation have shown no effect during a short period of trial. The literature is full of statements concerning the efficacy of intermittent proximal occlusion of the affected artery in improving the collateral circulation. In some cases the evidence that such an effect is being achieved is obvious,[16] but in many cases it is difficult to see any beneficial result. It would be a significant contribution to the problem of the treatment of aneurysms and fistulas if some controlled experimental and preferably clinical studies should establish beyond question the value and the limitations, as well as the criteria for continuing or abandoning such procedures. With the present state of knowledge, it is my belief that sympathectomy is indicated if no definite improvement in the tests for collateral circulation follows such efforts carried out during a period of some weeks. It is well established that permanent partial occlusion of the proximal artery is sometimes helpful in increasing the collateral circulation in cases of arterial aneurysm. This procedure is not applicable in instances of arteriovenous fistula.

Since sympathectomy in cases of aneurysm is as simple as partial proximal ligation and probably safer, and since partial proximal ligation may jeopardize the chance of successfully maintaining or re-establishing the continuity of the

involved artery once operation is attempted, sympathectomy appears to me as the wiser procedure. In the majority of cases in this series in which sympathectomy was carried out because of poor tests for collateral circulation, these tests became satisfactory fairly promptly. Even in those difficult cases in which the tests did not become adequate, the procedure gave one some definite satisfaction in the knowledge that vasoconstriction had been eliminated.

Where the aneurysm or fistula is associated with a peripheral nerve lesion which requires operative treatment and where the collateral circulation is precarious, the indication for sympathectomy seems clear-cut. It is imperative that the nerve lesion be treated early rather than late, and it is too hazardous to attempt nerve repair before operative cure of the aneurysm or fistula; any effort to improve the collateral circulation so as to permit early operative treatment is worth while. Similarly, sympathectomy seems advisable when such vascular and nerve lesions are associated with obvious evidence of impaired circulation in the extremity regardless of whether the collateral circulation appears to be adequate or inadequate. In such cases one must presume that operative cure will necessitate ligation of the artery and further reduction in circulation to the limb, and it seems apparent that a good vascular supply fosters nerve regeneration just as impaired circulation may produce ischemic nerve injury. My data are insufficient for quantitative comparison of nerve regeneration in patients with nerve injuries with unimpaired circulation and in those with ligated arteries in limbs which have been sympathectomized, but they give one the impression that nerve restoration is comparable in the two groups. The data do offer conclusive proof that sympathectomy may be of great benefit in cases of ischemic nerve injury with impaired circulation resulting from arterial ligation, division, or thrombosis, a subject which will be presented in another communication.

Sympathectomy may be advisable in certain cases in which the anatomic location of the aneurysm or fistula prevents digital occlusion of the artery and in which the artery affected is one of those the ligation of which is sometimes followed by ischemic troubles. When the artery cannot be compressed precisely at the site of its defect, one can sometimes compress it proximally or distally and obtain some notion of the state of the collateral circulation. It must be kept in mind, however, that such tests may give erroneous results either through the occlusion of collateral channels which can be preserved during operative attack upon the lesion, or through nonocclusion of channels which may have to be sacrificed.

Where ischemic lesions are present distal to an aneurysm or fistula, sympathectomy is entirely rational. Cure of the aneurysm or fistula may entail ligation of the artery and still further reduction in circulation. Even if the blood flow through the artery can be preserved there is every need for increasing the circulation, which is obviously insufficient as evidenced by the ischemic lesion present.

If the main artery to a limb must be ligated in the cure of the vascular lesion, one can ill afford the risk of having the circulation jeopardized by vasospasm in the collaterals. It must be pointed out that vasospasm is not

present in every limb in which a main arterial stem is ligated. Indeed, the vascular tone after such ligations may be high, low, or normal. In some cases the limb actually exhibits evidence of vasodilatation and increased stability of skin temperature under varying environmental circumstances, suggesting the effect of periarterial sympathetic interruption consequent to ligation and division of the artery. Where there is previous evidence of pronounced vasospasm it appears unwise, however, to take any risk regarding its possible occurrence after operation. Such cases might be handled in two ways. One might proceed with operation and, if alarming vasospasm ensues, attempt to control it by sympathetic blocks or, if necessary, by sympathectomy. One might, on the other hand, prefer to take no risk and to perform sympathectomy either before the other operation or at the same time, if the tests for collateral circulation are good. The latter seems to me the safer method and hence is recommended in selected cases where there is intense vasospasm.

Sympathectomy may be required in the occasional case in which one or more of the main arteries to a limb have already been occluded by previous injury or operation and in which cure of an aneurysm or fistula may require ligation of other arteries essential to nutrition and proper function. Similarly an occasional case will be encountered in which an aneurysm or fistula is associated with severe causalgia which can be temporarily relieved, although not cured, by sympathetic blocks.

Sympathectomy and the operation for cure of the aneurysm or fistula need not always be performed as separate procedures but can often be carried out at the same time. This can undoubtedly be done more often than it was in the present series of cases. Unless one has good evidence of unquestionably adequate collateral circulation beforehand, one should, under these circumstances, always test the collateral circulation immediately after sympathectomy is accomplished and proceed with or abandon operative attack upon the aneurysm or fistula according to the results of such tests.

In all cases in which some specific indication for its use does not exist, there appears to be no point in performing sympathectomy. If the indications already described are observed as a basis for the use of sympathectomy, one will undoubtedly carry out the procedure sometimes, when in retrospect it is seen that it might have been safely omitted. This will occur chiefly in those cases in which one will find it possible to maintain the continuity of blood flow through the affected artery by some reparative procedure. Since the feasibility of carrying out such procedures cannot be foreseen and since one cannot rely upon successful maintenance of blood flow in every instance in which they are attempted, it is the part of wisdom to make as certain as possible that the collateral circulation is adequate before attempting extirpation of any aneurysm or fistula. If such practice means the performance of an occasional unnecessary sympathectomy, it is nevertheless wise. Sympathectomy will also be done needlessly if an aneurysm or fistula is improperly localized. Fortunately, there is seldom any difficulty in localizing accurately the site of the lesion. Difficulty is most often encountered in cases of high lesions of the profunda femoral artery where digital pressure sufficient to still an aneurysm or abolish the bruit and

thrill of a fistula generally compresses the overlying femoral artery. As mentioned previously, arteriograms should ordinarily permit one to establish the correct localization in such cases.

It is also undoubtedly true that patients will be treated in whom operative cure of the aneurysm or fistula might have been accomplished without preliminary sympathectomy and without the occurrence of gangrene or ischemic paralysis. Where such serious complications appear to offer a definite threat, it seems wise, however, to take every precaution to avoid them. One cannot afford to gamble with the viability of a patient's arm or leg. Indeed, as the reported series of cases illustrates, such disasters may occur even if sympathectomy is performed, and it should be emphasized that the procedure offers no guarantee that some ischemic difficulty may not occur after ligation of an important artery. The utmost care in testing the collateral circulation and in avoiding injury to collateral vessels at the time of operation must be exercised, or else the use of sympathectomy is doomed to be associated at times with disastrous results. The procedure must be looked upon as an aid in, but not as a sure preventive of, ischemic troubles.

In assaying the worth of sympathectomy, two additional problems must be considered, namely, its effect upon fatigue on exercise and upon sensitivity to cold in limbs in which operative cure of aneurysm or fistula has necessitated ligation of an important artery. These are the commonest important symptoms in limbs in which otherwise adequate circulation has been maintained. Unfortunately, analysis of this problem is difficult. Some idea can be obtained, however, by comparing the exercise tolerance, before onset of fatigue, of patients who had operations requiring ligation of the femoral or popliteal artery without preliminary sympathectomy and those with sympathectomy, and by comparing the incidence of cold sensitivity in patients with and without sympathectomy, who had ligations of the axillary, brachial, femoral or popliteal arteries. There was no essential difference in exercise tolerance in this series whether sympathectomy was performed or omitted. It has been pointed out that the two groups cannot be controlled properly in certain important regards. As will be discussed in another paper,[13] most of those patients in whom sympathectomy was performed after operative cure of aneurysm or fistula had only slight increase in exercise tolerance after this procedure, or none at all, although striking improvement was noted in some. One can form no well-founded conclusions in regard to this problem, but one gets the impression that sympathectomy rarely has any marked beneficial effect upon exercise tolerance. Although cold sensitivity occurs sometimes after ligation of arteries in the treatment of aneurysms and fistulas in patients who have had sympathectomy, such disorders are more common and more severe in those in whom sympathectomy has not been carried out.

In his original publications, Gage[3, 4] called attention to the frequent occurrence following sympathetic denervation of extensive thrombosis within the sac of the aneurysm. DeBakey[17] had one case of a fistula of the carotid-cavernous sinus in which cure by thrombosis took place after sympathectomy. Colson and Giddy[18] performed lumbar sympathectomy in preparation for exploration

of a popliteal aneurysm and noted progressive thrombosis of the sac within a few days. An apparently satisfactory cure was obtained which obviated the necessity for operative treatment. In the present series of cases, extension of the mural thrombus within the sac was often noted and in two instances a "cure" by thrombosis followed sympathectomy. Since "spontaneous cure" by thrombosis occurs occasionally, it is impossible to state that a cause-effect relationship exists when a "cure" follows sympathectomy, although the march of events in certain cases would suggest this to be true.

SUMMARY

1. A series of seventy-eight cases is reviewed in which sympathectomy was used as an adjuvant in the operative treatment of aneurysms and arteriovenous fistulas.

2. The indications for this procedure are outlined.

3. Its value and its limitations are discussed.

4. Sympathectomy is a valuable aid in the treatment of aneurysms and fistulas. It does not, however, afford a guarantee against ischemic difficulties.

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SYMPATHECTOMY AS AN ADJUVANT IN THE OPERATIVE TREATMENT OF ANEURYSMS AND ARTERIOVENOUS FISTULAS

II. Sympathectomy Performed After Operation

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THE role of sympathectomy as a preliminary to operations for the cure of aneurysm or arteriovenous fistula has been discussed elsewhere.[1] The usefulness of this procedure in increasing the efficacy of the collateral circulation, in providing the limbs with the maximal or near-maximal circulation possible, in influencing favorably existing ischemic difficulties, and in alleviating such associated conditions as causalgia makes it evident that sympathectomy might also be of benefit in attempting to correct certain circulatory conditions which sometimes follow the operative treatment of aneurysms and fistulas. Similarly, experience with sympathectomy in other disorders in which blood flow through an important artery has been interrupted by disease, injury, or operation suggests that this procedure would be of value in the problem under discussion. It is the purpose of this communication to record the results of this procedure in thirty-eight cases.*

Circulatory disorders after the operative cure of aneurysms and fistulas can be lessened by careful tests for collateral circulation as a guide to the selection of the proper time for operation, and by exact operative technique which insures avoidance of injury to the collateral blood supply. They can be eliminated for all practical purposes when the continuity of blood flow through the involved artery is maintained or restored by means of some reparative procedure, methods which can be successfully applied to a considerable number of cases if this possibility is kept in mind and is utilized whenever applicable.[2] Nevertheless, these difficulties do occur occasionally in spite of all efforts to avoid them.

CLINICAL MATERIAL

In the present series of cases, 290 aneurysms and fistulas were operated upon, 13 cases were observed in which a satisfactory "cure" by thrombosis occurred, and an additional 63 cases were studied following operative cure performed elsewhere by other surgeons. Sympathectomy was performed before or at the time of operation upon 76 of the 290 patients whom I treated by operation and upon one of the 62 who had been operated upon by others, and

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*Two cases included in a previous report[1] are also included here, since in each sympathectomy followed excision of one arteriovenous fistula and was performed before excision of another.

it was carried out in 2 of the 13 cases in which a "cure" by thrombosis subsequently occurred (Table I). Sympathectomy was performed after operation in 19, or 8.9 per cent, of the first group of cases and in 18, or 29 per cent, of the second. Sympathectomy was also performed subsequently in one patient who had undergone a "spontaneous cure."

TABLE I. SYMPATHECTOMY IN CASES OF ANEURYSM AND ARTERIOVENOUS FISTULA

	PATIENTS OPERATED UPON AT MAYO GENERAL HOSPITAL			PATIENTS OPERATED UPON ELSEWHERE			PATIENTS IN WHOM "CURE" BY THROMBOSIS OCCURRED		
	A-V FISTULA	ANEURYSM	ALL	A-V FISTULA	ANEURYSM	ALL	A-V FISTULA	ANEURYSM	ALL
Patients sympathectomized before or at time of operation or with "spontaneous cure"									
No.	47	29	76	0	1	1	1	1	2
Per cent of total	22.8	34.5	26.2	0	3.4	1.6	20	12.5	15.4
Patients without sympathectomy before operation or "spontaneous cure"									
	159	55	214	34	28	62	4	7	11
Patients sympathectomized after operation or "spontaneous cure"									
No.	11	8	19	8	10	18	0	1	1
Per cent of those not previously sympathectomized	6.9	14.8	8.9	23.5	35.7	29	0	14.3	9.1
Total patients sympathectomized									
No.	58	37	95	8	11	19	1	2	3
Per cent of all cases	27.7	44	32.8	23.5	39.3	30.6	20	25	23.1
Total No. Cases	206	84	290	34	29	63	5	8	13

It is of interest that sympathectomy was carried out before or at the time of operation in 26.2 per cent of the group operated upon at the Mayo General Hospital and in only 1.6 per cent of the group operated upon elsewhere, and that the incidence of sympathectomy before and after operation was essentially the same in the two groups (32.8 and 30.6, respectively). It is also interesting that sympathectomy was performed more frequently in cases of arterial aneurysm than in cases of arteriovenous fistula, the percentage of cases of arterial aneurysm in which this procedure was carried out after operation being 14.8 in the group treated at the Mayo General Hospital and 35.7 in the group treated elsewhere, whereas the percentage of cases of arteriovenous fistulas in which the procedure was carried out was 6.9 and 23.5 in the two groups. Similarly, the percentage in which sympathectomy was performed either before or after operation was 44 in cases of arterial aneurysm and 27.7 in cases of arteriovenous fistula in the first group, and 39.3 in cases of aneurysm and 23.5 in cases of fistula in the second group.

The chief indications for operation have been as follows: (1) distressing sensitivity of the limb to cold; (2) associated severe peripheral nerve damage in limbs in which the circulation was definitely impaired; (3) persistent edema; (4) ischemic nerve paralysis; (5) causalgia relieved temporarily but not cured by sympathetic blocks; (6) obviously impending gangrene; (7) evidence of sympathetic overactivity, with or without poor collateral circulation, in a limb in which another arteriovenous fistula required excision.

In three of the cases included (Cases 6, 7, and 8, Table V), sympathetic interruption was carried out by surgeons in other hospital installations. In one of them (Case 7, Table V) alcohol injection was performed. In the remainder, sympathectomy was carried out. Ganglionectomy through an anterior extraperitoneal approach was performed for the lower extremities; the Smithwick type of preganglionic operation was done for the upper extremities. Sympathetic interruption was carired out in twenty-one lower and in eighteen upper extremities. No deaths and no serious complications occurred.

RESULTS OF THE PROCEDURE

The data concerning the thirty-eight cases are summarized in Tables II to V, being grouped in the various tables according to the primary indication for sympathectomy. In many cases there were several circumstances which influenced the decision to perform sympathectomy. These and other relevant data are included in the tables.

SYMPATHECTOMY PERFORMED BECAUSE OF SENSITIVITY OF THE LIMB TO COLD

The commonest circulatory difficulty for which sympathetic interruption was carried out was sensitivity of the affected limb to cold. The data upon 17 such cases are summarized in Table II. Nine patients had arterial aneurysms and 8 had arteriovenous fistulas. Nine patients had involvement of an upper extremity and 8 had involvement of a lower extremity. The vascular lesions for which arterial ligation had been necessary involved the subclavian artery in 3 cases, the axillary in 1, the brachial in 5, the external iliac in 1, the femoral in 6, and the popliteal in 1. In one instance the aneurysm had been "cured" by spontaneous thrombosis; in the other cases excision of the lesion had been carried out. Seven of these operations had been performed overseas and 9 at the Mayo General Hospital. The duration of the lesion at the time of operation ranged from 1 to 4 months (average 1.6 months) in the first group, and from 2.5 to 11 months (average 5.7 months) in the second.

All the patients had annoying coldness of the affected hand or foot upon exposure to cold and most of them had cyanosis, mild in some, severe in others. All had discomfort during such exposure; by some this was described as an aching, by others as a burning or tingling sensation. Most of them had some degree of numbness of fingers or toes and nearly all complained of stiffness of fingers or toes. When paresis was present it was aggravated during exposure to cold, and existing pain, paresthesias, or hypesthesia usually became more

TABLE II. SYMPATHECTOMY PERFORMED AFTER OPERATION FOR ANEURYSM OR FISTULA, OR AFTER "SPONTANEOUS CURE," INDICATION—COLD SENSITIVITY

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND OPERATION (IN MO.)	INTERVAL BETWEEN OPERATION AND SYMPATHECTOMY (IN MO.)	TYPE OF OPERATION	COMMENT	RESULT
			Arteriovenous Fistulas			
1	Subclavian	4	5	E*	Extreme *c.s.*, fatigability	Relief
2	Subclavian	4	2	E	Marked *c.s.*, fatigability	Relief
3	Subclavian	3	2	E		Relief
4	Brachial	2	2	E	Marked *c.s.*, vasospasm, pain aggravated by cold exposure, ulnar palsy; fistula discovered during neurosurgical exploration	Relief, loss of pain
5	Femoral	2.5	3	E	Marked *c.s.*	Relief
6	Femoral	2.2	4	E*		Relief
7	Femoral	1	3.5	E*		Relief
8	Femoral	1	5	E*	Partial sciatic paralysis, pain in foot	Relief, pain improved
			Arterial Aneurysms			
9	Axillary	5	1.5	E	Also severe plexus injury, circulation impaired	Relief, circulation improved; nerve return satisfactory except for radial; tendon transplant
10	Brachial	6	0.7	E	Also mild causalgia, median palsy, circulation impaired	Relief, circulation improved, causalgia largely relieved; nerve return satisfactory
11	Brachial	7.7	0.7	E	Cold sensitivity before and after operation, ulnar palsy	Relief, nerve return satisfactory
12	Brachial	7	1	E	Also median palsy	Much improved, satisfactory nerve return
13	Brachial	"spontaneous cure" 1.5; excision thrombosed artery 6	6	E Excision thrombosed artery	Also median palsy, neurolysis	Relief, excellent return of nerve function
14	Ext. iliac	11	1	E	Also frostbite, marked *c.s.* with pain and hypesthesia	C.S. persists though considerably improved; burning persists
15	Femoral	1	6	E*	Marked *c.s.*	Relief
16	Femoral	1	5	E*		Relief
17	Popliteal	1.2	6.5	E*	Sciatic palsy, pain in foot	Relief, pain improved

*In this and following tables an asterisk signifies that the operation was performed overseas. Abbreviations in this and following tables: E, excision; A, aneurysmorrhaphy or similar procedure; A-E, aneurysmorrhaphy or similar procedure followed by excision of sac; *c.s.*, cold sensitivity.

intense. The affected hand or foot was generally warm and well colored in a warm environment. One patient (Case 5), for example, had a warm, well-colored foot at all times under ordinary circumstances and showed no evidence of circulatory insufficiency except for the usual fatigue on exercise. He lived, however, in Minnesota, and on exposure to cold the foot became icy cold and numb and ached severely. There was no improvement in this regard over a period of months. Complete relief followed sympathetic ganglionectomy. It was my practice to test each patient's ability to withstand exposure to cold. If only mild manifestations of sensitivity were present, or if more marked symptoms occurred on exposure to severe cold in a patient who planned to live in a warm part of the country, it was felt that the condition would cause little discomfort or disability. It was equally apparent that such symptoms were of considerable importance to persons who lived in a cold climate. The situation was explained to these patients; they were allowed to compare the reaction of the limb to a cold environment under ordinary circumstances and during a period of sympathetic procaine anesthesia, and the choice of operation was offered to them. Except for a very few who felt that their work, avocations, and general interests made prolonged exposure to the outside cold unnecessary, all elected to have sympathectomy performed. The advice of their fellow patients who had undergone this procedure for similar complaints undoubtedly influenced the choice of many.

It will be noted that eight of the patients had, in addition, associated peripheral nerve lesions. A few had evidence of sympathetic overactivity under ordinary environmental circumstances, and in one this vasospasm was rather pronounced. Several had obvious evidence of impaired circulation. One patient had mild causalgia. One had sustained a fairly severe frostbite of the feet at the time of the injury, which produced the external iliac aneurysm. In this patient the frostbite contributed to the cold sensitivity which was, however, much more severe in the limb in which the external iliac artery had been divided.

The results of sympathectomy were excellent. In all except two patients complete relief was obtained, and in these two definite improvement was noted. The pain was much improved in the patient with causalgia, as it was in all other instances in which pain had been present, with the exception of the patient with frostbite, who continued to have some mild burning in the foot. The nerve regeneration was as satisfactory as could be expected from the trauma sustained.

SYMPATHECTOMY PERFORMED BECAUSE OF ASSOCIATED PARALYSIS AND IMPAIRED CIRCULATION

In Table III data are given concerning five patients upon whom sympathectomy was performed in an attempt to improve impaired circulation in order to afford maximal opportunity for repair of extensively damaged peripheral nerves. In all there was evidence of reduced blood flow and severe nerve damage. Most of them were cases in which sympathectomy had been consid-

TABLE III. SYMPATHECTOMY PERFORMED AFTER OPERATION FOR ANEURYSM OR ARTERIOVENOUS FISTULA; INDICATION—REDUCED BLOOD SUPPLY AND SEVERE NERVE DAMAGE

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND OPERATION (IN MO.)	INTERVAL BETWEEN OPERATION AND SYMPATHECTOMY (IN. MO.)	TYPE OF OPERATION	COMMENT	RESULT
			Arteriovenous Fistulas			
1	Axillary	6.5	0.7	E	Had had lysis of brachial plexus and ulnar neurorrhaphy	Circulation excellent; good nerve return
2	Axillary	5	1	E	Had had lysis of plexus and suture of posterior cord, also some *c.s.*	Circulation better; slight *c.s.* remains, nerve return satisfactory
			Arterial Aneurysms			
3	Subclavian	2.5	0.7	A	Severe plexus damage, no surgical repair possible; causalgia, improved after operation	Circulation much improved; good nerve return except for posterior cord; comfortable
4	Axillary	2.5	1	A	Extensive plexus damage, circulation impaired, much sensitivity of hand	Hypersensitivity of hand relieved, some immediate nerve return, subsequent satisfactory progress
5	Brachial	1	1.5	E*	Had lysis of ulnar and suture median nerve, some *c.s.*	C.S. relieved, satisfactory nerve return, circulation improved

ered before operation but had been deferred because of evidence of excellent collateral circulation and in the hope that the damage to the nerve might prove at exploration to be due in large part to pressure of the aneurysm or might prove to be less severe than was anticipated. In all of them the neurological condition observed at operation was disappointing in this regard. In addition, one patient had extremely impaired circulation, one patient had extreme hyperesthesia of the hand, and two had some sensitivity of the part to cold. It will be noted that four were cases of arterial aneurysm and two were cases of arteriovenous fistula. It will also be noted that all except one were cases of injury to the brachial plexus and that all the vascular lesions involved the subclavian, axillary, or brachial vessels. The results were gratifying. Signs of nerve regeneration indicate as satisfactory progress as might be hoped for considering the extent of the nerve damage. The circulation in the limb was visibly improved. The sensitivity to cold was relieved or improved.

SYMPATHECTOMY PERFORMED BECAUSE OF PERSISTENT EDEMA

Data concerning six patients in whom sympathectomy was performed because of persistent edema are given in Table IV. The edema in these patients ranged from moderate to massive. All had failed to improve under conservative measures such as rest and elevation of the limb, elastic support, and

TABLE IV. SYMPATHECTOMY PERFORMED AFTER OPERATION FOR ANEURYSM OR ARTERIOVENOUS FISTULA; INDICATION—EDEMA

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND OPERATION (IN MO.)	INTERVAL BETWEEN OPERATION AND SYMPATHECTOMY (IN MO.)	TYPE OF OPERATION	COMMENT	RESULT
			Arteriovenous Fistulas			
1	Popliteal	3	0.5	E	Saccular aneurysm as well as A-V; subcutaneous rupture had caused peroneal palsy; after operation had fairly marked edema, foot was cool	Marked improvement, foot warmer, edema much less, subsequently disappeared, good nerve return
2	Popliteal	6	1	E	Marked edema, foot cool	Edema moderately improved, foot warm
3	Posterior tibial	2	0.8	E	Moderate edema, some coolness, cyanosis, and hyperhidrosis; temporary relief and reduction in edema from sympathectomy blocks but no lasting effect	Edema almost completely disappeared, foot warm and well colored
4	Posterior tibial	2	6	E*	Persistent edema, some cyanosis of foot	Edema considerably less
			Arterial Aneurysms			
5	Popliteal	0.5	2.5	A*	Marked edema; cyanosis of foot, ulcers of leg, peroneal palsy, tibial palsy, questionably due to postoperative ischemia	Marked improvement, edema minimal, ulcers healed

gradually increasing periods of exercise. Sympathetic blocks had resulted either in only transient diminution in swelling or in no noticeable effect except for temporary warmth and dryness of the foot. In addition to edema, two patients had paralysis of nerves, all had some cyanosis, coolness of the affected foot, or hyperhidrosis, and one had indolent ulcers. Four had an arteriovenous fistula, 1 an arterial aneurysm, three a popliteal fistula or aneurysm, and two a posterior tibial fistula. Two patients had been operated upon overseas at a time when the vascular lesion was of two weeks' duration and two months' duration, respectively. Three patients were operated upon at the Mayo General Hospital; the lesions were of two, three, and six months' duration. Sympathectomy was performed from two weeks to six months after operation. The results were fair in one case (Case 2), somewhat better in another (Case 4), and excellent in the others. In addition to the effect upon the edema, warmth and good color prevailed in all the limbs treated. Satisfactory return of nerve function took place.

TABLE V. SYMPATHECTOMY PERFORMED AFTER OPERATION FOR ANEURYSM OR ARTERIOVENOUS FISTULA; MISCELLANEOUS INDICATION

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND OPERATION (IN MO.)	INTERVAL BETWEEN OPERATION AND SYMPATHECTOMY (IN MO.)	TYPE OF OPERATION	COMMENT	RESULT
			Arteriovenous Fistulas			
1	Femoral	2	3	Transsaccular ligation*	Stocking hypesthesia up to just below knee, foot largely anesthetic; extensor paralysis toes 1 and 2, ischemic palsy following operation	Anesthesia gone, hypesthesia only of foot, regained extension of toes; improvement began within few days after sympathectomy
2	Femoral	0.2	3.5	E*	Boot anesthesia and complete tibial and peroneal paralysis followed operation, regained tibial function promptly; on admission peroneal motor loss complete, sensory almost complete	Improvement began within few days; complete recovery
3	External iliac	1.7	3.3	E*	Some *c.s.*, poor collateral circulation; a second (hypogastric) A-V fistula remained to be excised	Excellent, good circulation following excision of hypergastric fistula; no *c.s.*
4	Cirsoid of foot	?	3	E	Hyperhidrosis and cyanosis followed excision post-tibial A-V; peroneal and anterior tibial A-V fistulas remained to be excised	Foot remained warm, dry, and well colored after remaining fistulas were excised
5	Femoral	8.5	0.2	E	Foot had excellent circulation until 6th P.O. day when arterial and venous thrombosis occurred with coldness, numbness and paresis of foot	Some improvement with descent of cold level; gangrene of toes and sole of foot occurred, however
			Arterial Aneurysms			
6	Brachial	1.5	3	E*	Complete paralysis upper extremity after injury, after several months gauntlet type anesthesia, etc., suggested residual paralysis was largely ischemic; hand cold, cyanotic	Marked improvement began after sympathectomy; steady, significant but incomplete return of function

TABLE V.—CONT'D

CASE NO.	LOCATION OF LESION	INTERVAL BETWEEN INJURY AND OPERATION (IN MO.)	INTERVAL BETWEEN OPERATION AND SYMPATHECTOMY (IN MO.)	TYPE OF OPERATION	COMMENT	RESULT
			Arterial Aneurysm—Cont'd			
7	Axillary	2.7	Same day	E*	Obviously impending gangrene of hand, especially of thumb, with marked ischemic paralysis, followed operation; also had traumatic plexus injury, treated by alcohol injection	Gangrene limited to thumb which was amputated; slow, steady, but incomplete recovery from ischemic and traumatic paralysis
8	Femoral	3.2	One day	A*	Foot extremely cold and pale after operation	Excellent, good color and warmth
9	Brachial	1	12	E*	Causalgia, severe *c.s.*, severe plexus injury including irreparable damage to musculocutaneous nerve	Causalgia relieved; cold sensitivity improved, nerve return satisfactory
10	Popliteal	0.5	0.75	E*	Causalgia and peroneal paralysis followed operation	Causalgia much improved
11	Profunda femoral	2	0.2	E	Moderate causalgia temporarily relieved by sympathetic block; tibial palsy, definite hypochondriasis	Immediate relief slight, subsequent complete relief with exercise and encouragement

SYMPATHECTOMY PERFORMED BECAUSE OF ISCHEMIC LESIONS, CAUSALGIA, AND OTHER CONDITIONS

In Table V data are summarized concerning 11 patients upon whom sympathectomy was performed for various other indications. Six were cases of arterial aneurysms and 5 cases of arteriovenous fistula. The operations upon these lesions were performed overseas in 7 and at the Mayo General Hospital in 4 cases.

Ischemic paralysis was the primary indication for sympathectomy in 3 patients (Cases 1, 2, and 6). In 2, the neurological difficulty followed operation for the cure of a femoral arteriovenous fistula. The clinical records of these patients contained no data concerning the state of collateral circulation before operation. In one patient there was extensor paralysis of two toes, anesthesia of the foot, and stocking hypesthesia almost up to the knee. Improvement began promptly after sympathectomy and progressed over the ensuing weeks. Motor power returned to the toes, the hypesthesia disappeared from the leg, and the foot was no longer anesthetic though still hypesthetic. The other patient had a stocking anesthesia with complete sciatic paralysis after operation. Return of function in the tibial nerve was prompt, but at the time of admission the patient had complete peroneal motor loss and nearly complete

sensory loss. The neurological condition appeared stationary. Return of peroneal function was noted within a few days after sympathectomy and progressed steadily thereafter to complete recovery. The third patient had paralysis of the upper extremity after injury, when he was examined, 3 months after excision of an axillary aneurysm and 4½ months after injury, the gauntlet type of anesthesia and other findings made it evident that the residual paralysis was largely ischemic in nature. The hand was cold and cyanotic and ached upon exposure to cold. Improvement was noted shortly after sympathectomy, the anesthesia receding in a glovelike fashion. Nine months after sympathectomy there was normal sensation except for hypesthesia of the dorsum of the hand and anesthesia of the palmar surface of the fingers. Return of motor function had been considerable but incomplete. The hand was well colored, warmer, and withstood exposure to cold fairly well.

Sympathectomy was carried out in two patients (Cases 3 and 4) with multiple arteriovenous fistulas. In the one there was some sensitivity to cold and evidence of very poor collateral circulation following excision overseas of an external iliac fistula. Another fistula which proved at operation to involve the neighboring hypogastric vessels remained to be excised. Immediately after sympathectomy the collateral circulation was retested and found adequate, and the hypogastric fistula was excised. The limb maintained excellent circulation. The other patient had a congenital cirsoid aneurysm of the foot with distinct fistulas of the anterior and posterior tibial and peronal vessels. Excision of the posterior tibial fistula was followed by extreme hyperhidrosis and cyanosis of the foot which persisted over a period of months. The foot remained warm and dry after sympathectomy. The other fistulas were resected without difficulty.

Sympathetic interruption was carried out in two patients because of obvious impending gangrene (Cases 5 and 7). One patient who had maintained good warmth and color in the foot after excision of a femoral arteriovenous fistula suddenly noted pain and swelling in the foot and leg with coldness, numbness, and paresis of the foot. It was apparent that extensive arterial and venous thrombosis had occurred. There was little improvement in circulation during spinal anesthesia, but because of the desperate situation, sympathectomy was performed. Actually, the cold level decreased and sensation improved. The improvement in circulation was insufficient, however, to prevent gangrene of the toes and sole of the foot, and amputation was necessary. The other patient was operated upon overseas nearly three months after an injury which had produced partial paralysis of the brachial plexus. An aneurysm of the axillary artery which was unexpectedly encountered was excised. After operation the hand was cold and cyanotic, and the thumb in particular seemed devoid of circulation. Successful alcohol injection of the dorsal sympathetics was accomplished. Gangrene of the thumb occurred and the thumb was amputated. In the rest of the hand there was restoration of fairly good circulation. A definite ischemic paralysis had been added to the pre-existing damage to the plexus. Steady improvement in nerve function followed but recovery was incomplete. In a third patient (Case 8) sympathec-

tomy was performed the day after aneurysmorrhaphy because the foot was alarmingly cold and pale. The foot regained good warmth and color.

In three patients sympathectomy was done because of causalgia (Cases 9, 10, and 11). All had peripheral nerve damage and one had severe sensitivity to cold. In all, temporary relief but no lasting effect followed a series of sympathetic blocks. The causalgia was relieved in one and much improved in another. The third patient continued to complain of pain after operation. He had, in addition, other complaints which gave evidence of hypochondriasis. The pain disappeared with reassurance and exercise.

There remains to be discussed the effect of sympathectomy upon the fatigue on exercise which occurs in a striking fashion in the lower extremity after ligation of the iliac, femoral, or popliteal artery and in a less noticeable degree in the upper extremity after ligation of the subclavian, axillary, or brachial artery. Ability to exercise the upper extremity was measured manometrically by having the patient squeeze, once every second, a rubber bulb which was connected through a 5 gallon bottle with a mercury manometer. The number of such squeezing movements performed before prohibited by fatigue were recorded, as well as the height of the manometer at the end of the test. Exercise tolerance in the lower extremities was estimated by the number of yards a patient could walk at a normal pace before he had to stop because of fatigue or, less commonly, cramps in the calf. The distance was measured by a pedometer or by having the patient walk over a measured course. Unfortunately, the number of patients upon whom such studies were carried out before and after sympathectomy and in whom there was no real limitation to exercise because of associated fractures or motor paralysis is too few to make statistically significant analysis possible. Those patients who had sympathectomy after ligation of the femoral or popliteal artery for the cure of aneurysm or fistula had fatigue or cramps after walking an average of 0.82 mile, which is approximately the same as in those patients treated for similar lesions without sympathectomy.[1] Many of the patients showed no improvement in tests for exercise tolerance after sympathectomy; many showed only slight improvement. A few, however, noted a striking increase in exercise tolerance. For example, on admission five and one-half months after excision of a femoral aneurysm, one patient (Case 15, Table II) was forced to stop after walking one-half mile because of aching and fatigue in the calf. Sympathectomy was performed because of sensitivity of the foot to cold. Within two weeks he could walk two miles before getting fatigue in the calf. Such improvement is exceptional, however.

Comparison of the series of patients operated upon overseas and those treated at the Mayo General Hospital may be profitable from the standpoint of factors influencing the occurrence of postoperative difficulties for which sympathectomy is required. If only those cases are considered in which the main arteries to the extremities were involved (innominate, subclavian, axillary, brachial, external iliac, common femoral, and popliteal arteries), 17 of 43 patients in the first group were treated by sympathectomy (39.5 per cent) and 17 of 184 patients in the second group (9.2 per cent). If those cases are

eliminated in which sympathectomy had been carried out before or at the time of operation and also those cases in which the continuity of blood flow through the affected artery was successfully maintained, the figures for the first group are 17 of 42 cases, or 40.5 per cent, and for the second group 17 of 108 cases, or 15.7 per cent. In each group sympathectomy was performed in one case partly because of the presence of another arteriovenous fistula which required excision. In general, the duration of the vascular lesion was shorter in the first group than in the second. The duration ranged from a few days to 4.5 months in the first group, or an average of 1.6 months. In only about 17 per cent was the duration 3 months or longer. In the second group the duration ranged from 6 weeks to 15 months, or an average of 5.1 months, excluding one case of 13 years' duration. In about 85 per cent the duration was 3 months or more.

Unfortunately the two groups are not entirely comparable. Early operation was apparently forced by complicating circumstances in a somewhat higher percentage of the patients operated on overseas than in those treated at the Mayo General Hospital. The patients in the first group were operated upon by numerous surgeons, whereas those in the second were treated by a few surgeons whose work was confined to the care of vascular disorders. Careful testing of the collateral circulation before operation was a routine procedure in the latter cases; judging from the clinical case records and interrogation of the patients, such tests were not carried out in those operated upon overseas. It is obvious then that the two groups are not comparable regarding these important factors. Nevertheless, the need for sympathectomy in a much higher percentage of these patients operated upon overseas suggests that postoperative circulatory difficulties are less frequent when operation is performed upon aneurysms or fistulas of relatively long duration. This hypothesis can probably be expressed more accurately by saying that the incidence of such difficulties will be less when the collateral circulation is established as adequate before surgery is undertaken, for although the collateral circulation tends to be better in cases of long duration, especially in the case of arteriovenous fistulas, there are frequent exceptions in which good collateral circulation is present in lesions of short duration and poor collateral circulation in lesions of long duration.

DISCUSSION

Circulatory difficulties following operative cure of peripheral aneurysms or arteriovenous fistula can be kept at a minimum by careful selection of the proper time for operation based upon exact testing of the collateral circulation and by avoidance of injury to the collateral blood supply during the operative procedure. These difficulties can be eliminated almost completely in those cases in which it is possible to maintain the continuity of blood flow through the affected artery. In spite of extreme care, however, certain patients treated for aneurysm or fistula are likely to have some circulatory disorders. These will not always be apparent from casual observation of the patient upon the wards. If it is our desire to provide these patients with the best possible limbs

and not merely to avoid such gross ischemic disasters as gangrene, more careful inquiry into the circulatory status is necessary. It is important to test the exercise tolerance of these limbs, to make certain that no distressing symptoms upon exposure to cold, no persistent edema, and no painful states or ischemic paralysis are present, and to be certain that the return of nerve function in cases of peripheral nerve injury is not compromised by inadequate circulation. In certain of these sequelae sympathectomy is of considerable benefit.

Next to diminished ability to exercise the limb without fatigue, cold sensitivity of the part is the commonest circulatory difficulty. In mild degree or in patients who live in warm climates, this is apt to cause no real discomfort or disability. When it exists in rather severe degree in patients whose place of residence and type of work require exposure to cold temperatures, the symptoms are distressing and often disabling. Sympathectomy yields excellent results in such cases. Preliminary sympathetic procaine blocks followed by exposure to a cold environment serve as a good guide to what may be expected of operative sympathectomy.

Persistent edema of significant degree is an unusual symptom. If present, it should be treated by rest and elevation of the limb, elastic support, and graduated activity with the limb dependent. If such measures are ineffectual, sympathetic blocks or sympathectomy may be of real value. Unfortunately sympathetic blocks are not a completely reliable index to what may result from permanent sympathetic interruption. If these blocks cause transient but not permanent diminution in swelling, sympathectomy is likely to be very helpful. If, on the other hand, no effect upon the edema is noted from procaine blocks, sympathectomy may also, in certain cases, be of benefit.

When ischemic difficulties are present, the efficacy of sympathectomy in correcting them depends upon the capacity of the collateral circulation to improve through the elimination of persistent or intermittent vasoconstriction and the maintenance of a state of vasodilatation. As with other disorders in which arterial blood flow has been interrupted, this capacity varies in different individuals. In my experience, sympathectomy has been strikingly successful in instances of ischemic nerve paralysis. The results in the two cases reported in which gangrene was imminent were less successful. In such cases the procedure should be given consideration, however, even if the limb shows only slight improvement with sympathetic block or spinal anesthesia. Occasionally, in instances of impending or spreading gangrene due to occlusion of arteries from other causes, sympathectomy has produced striking benefit even after such poor response to preliminary tests.

It is my belief that sympathectomy is indicated in cases in which severe nerve damage is associated with obviously impaired circulation and that the evidence of good nerve return in these cases has justified the procedure. Unfortunately, there are available no carefully controlled clinical studies comparing nerve regeneration in such cases in which sympathetic interruption has and has not been carried out. Sympathetic procaine block does not invariably give reliable information regarding the results which may follow

sympathectomy. If the nerve paralysis has not brought about sensory loss in the entire hand or foot, any improvement in circulation from sympathetic procaine block is readily demonstrable by skin temperature changes in the normally innervated digits. If, however, there is normal sensation (and intact sympathetic innervation) to no part of the hand or foot, no rise in skin temperature is ordinarily noted during sympathetic procaine anesthesia. That sympathectomy may actually increase the circulation in such cases is suggested by the decreased tendency to dependent cyanosis which is sometimes noted after operation, by diminution in cold sensitivity, occasionally by increase in oscillometry, but particularly by the striking improvement in nerve function which so often follows when part of the neurological damage is ischemic in nature. Obviously, when there is anesthesia of portions of the skin and consequently local sympathetic denervation, sympathectomy will not alter the tonus of blood vessels in the anesthetic skin. It is equally apparent that the blood flow in the limb can be increased by elimination of vasoconstriction from the vessels of the limb as a whole.

SUMMARY

1. The results of sympathectomy in attempting to correct certain circulatory difficulties following the operative cure of aneurysm or arteriovenous fistula have been studied in thirty-eight cases.

2. The indications for this procedure are outlined.

3. Sympathectomy seems to offer real aid in the correction of these postoperative circulatory disorders, although there are limitations to its achievements.

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REPAIR OF SKULL DEFECTS

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THE management of cranial defects has been repeatedly stressed in the literature in recent years, with particular emphasis on tantalum during the war. Many types of material have been used successfully and it is not necessary to repeat the various indications, contraindications, methods of preparation, and operative techniques at this time. Rather, the emphasis is on experiences using tantalum, bone, and cartilage in various situations during the past 3½ years on the neurosurgical and plastic surgical services at Valley Forge General Hospital. Sufficient time has elapsed to allow evaluation of some of the patients operated upon earlier both here and elsewhere, and certain problems have been encountered with each substance employed which deserves consideration for the proper management of cases of this type. One of us (W. G. P.) in collaboration with Robertson[4] has recorded results with the use of tantalum alone in 254 instances. This series now totals 279.

Tantalum has been the material preferred by the majority of the military neurosurgeons because of its malleability, strength, and limited tissue reaction. Its use has been justified further by the pressure of a great number of casualties during active warfare which demanded a simple, uniform method of cranioplasty, easily and rapidly performed by many surgeons, preferably in one stage. It has been possible to insert a tantalum plate successfully in a soiled field[3] or as early as 3 to 4 weeks after an active infection. However, the best end results have been obtained by waiting at least six months prior to further attempts at cranioplasty in cases of this type. This fact was recently stressed by Bradford and Livingston,[1] and is even more important when the use of bone is contemplated as it is much less tolerated in latently infected wounds. In either event, the patient is always well prepared with penicillin and sulfadiazine pre-and postoperatively. On the whole, the use of the tantalum has proved very satisfactory, particularly in large defects over the vertex. However, attention must be directed toward adequate scalp nutrition as previously pointed out[2] in that complete exposure of the bony margins is necessary for fixation of the plate.

Many have advocated multiple perforations of the tantalum plate prior to its insertion to facilitate adequate, subsequent absorption, to allow greater dissemination of local penicillin in event of infection, to provide an increased bed for adhesions and better fixation, and to improve vascularity in questionably viable superficial scars. Borderline cases of the latter type should be revised according to the principles already outlined[2] prior to or during cranioplasty. Since it is not possible to insert a plate "watertight" and inasmuch as the ultimate scar superficial and deep to the tantalum is ample for

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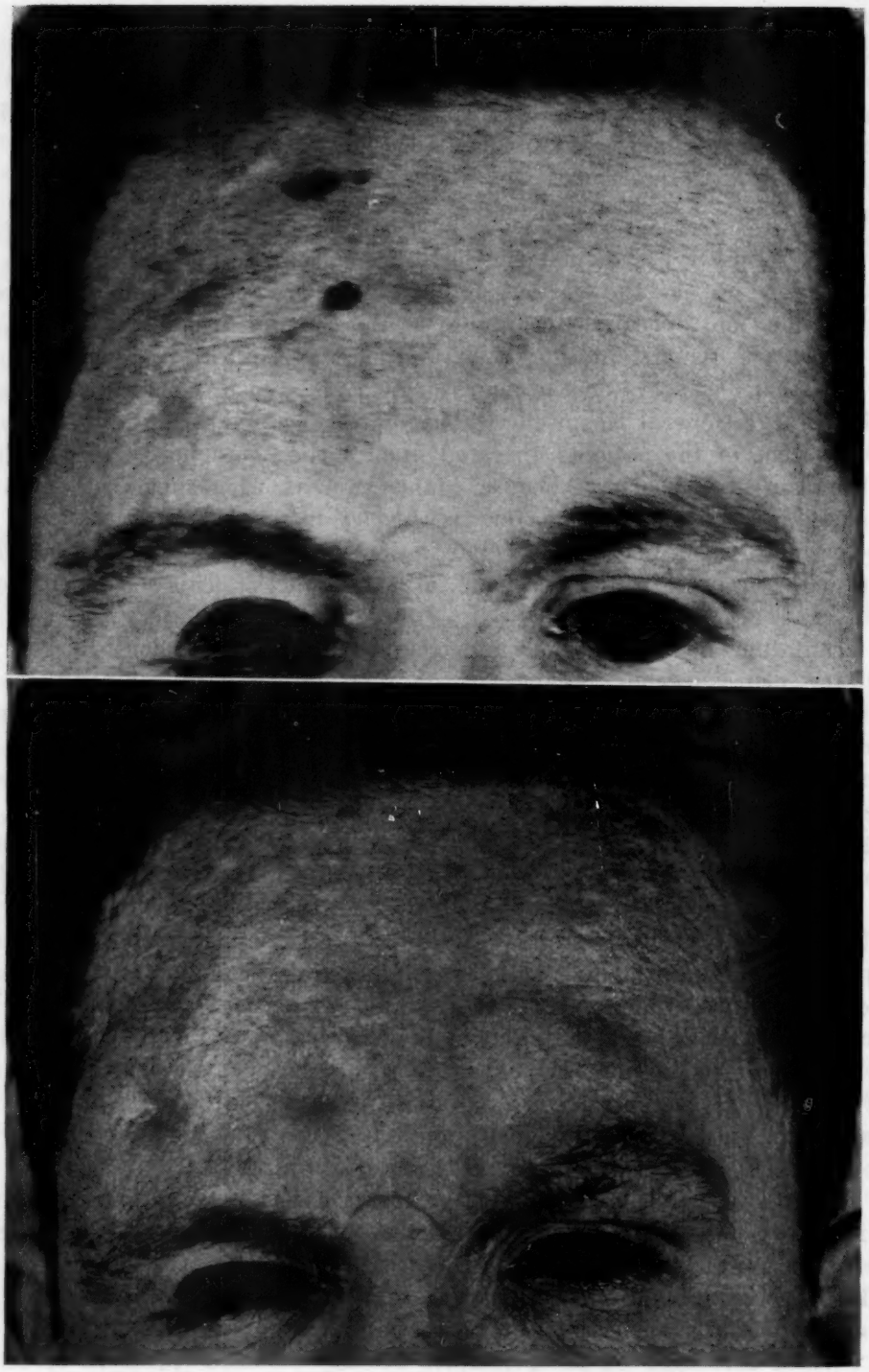
A.



B.

Fig. 1, *A* and *B*.—*A*, Postoperative tantalum cranioplasty over both supraorbital ridges. One small depression above right eyebrow at site of perforation in plate. *B*, Same patient ten months later with two depressed areas over right supraorbital ridge in vicinity of two large perforations in plate. Beginning depression above left eyebrow medially.

stabilization, it is not felt that such orifices present any material advantage. Further, the scar extending through such openings may contract over a period of time and produce noticeable disfigurement of the scalp, particularly in the frontal regions (see Fig. 1.).

The possible disadvantages in the use of tantalum may be the deleterious results of subsequent deep x-ray therapy or diathermy, and its radiopacity in event later complications develop necessitating roentgenographic examination; long term effects on the adjacent tissues are not yet available. Tantalum should be avoided where only limited exposure of the bony margins is possible, in children, in whom the growth factor must be considered and further bone regeneration anticipated, and in restoration of the complicated bony contours in vicinity of the supraorbital ridges, glabella, and nasal and zygomatic processes of the frontal bone. In these instances, the use of autogenous bone, either rib or ilium, is preferred. Both are well adapted to attain as nearly as possible the normal outlines of the skull.

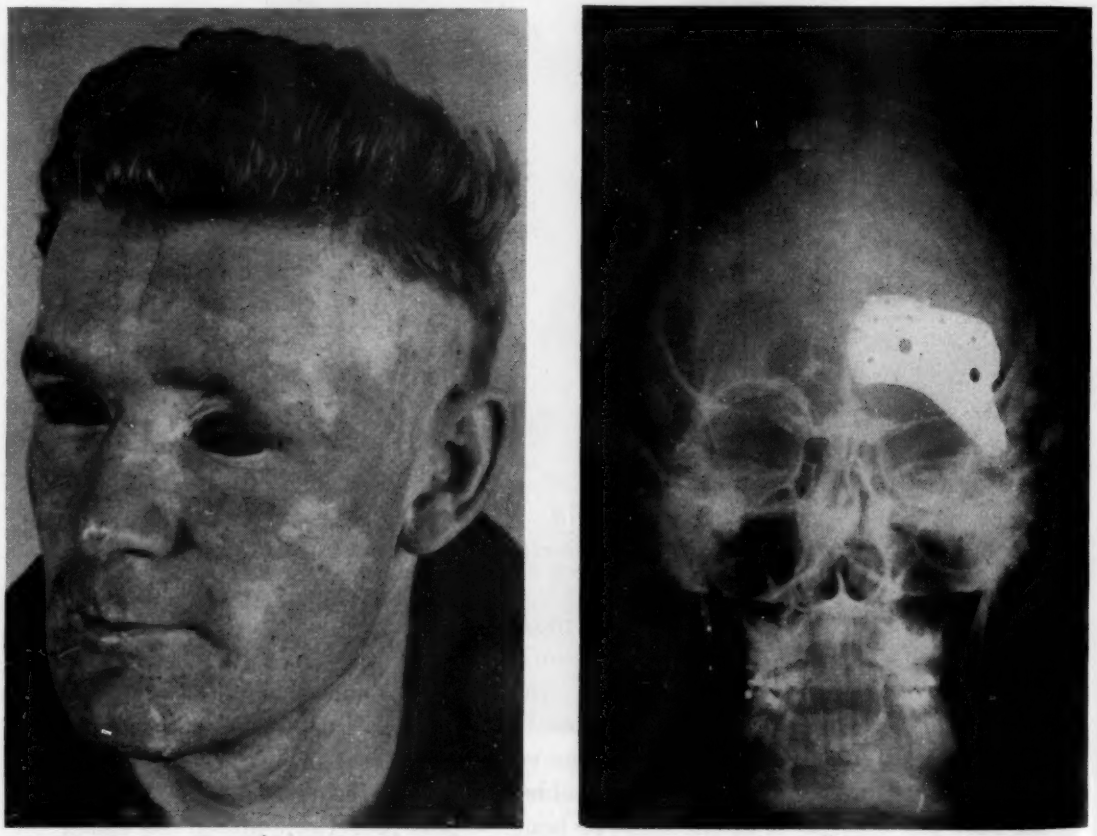
C.

Fig. 1, *C.*—Roentgenogram showing site of perforations in tantalum plate corresponding to previous scalp depressions.

At least eight cases have been observed recently in which a tantalum plate had been inserted over the supraorbital ridge elsewhere without achieving satisfactory cosmetic restoration. In these patients, the plate was found to be either too high (see Fig. 2) or too low (see Fig. 3), with such deformity as to have the individual seek further repair. Several procedures had been performed, usually in an attempt to achieve an improved result prior to transfer here for "insertion of cartilage or bone." It is preferable not to use either of these substances in the presence of tantalum, because firm union does

A. *B.*

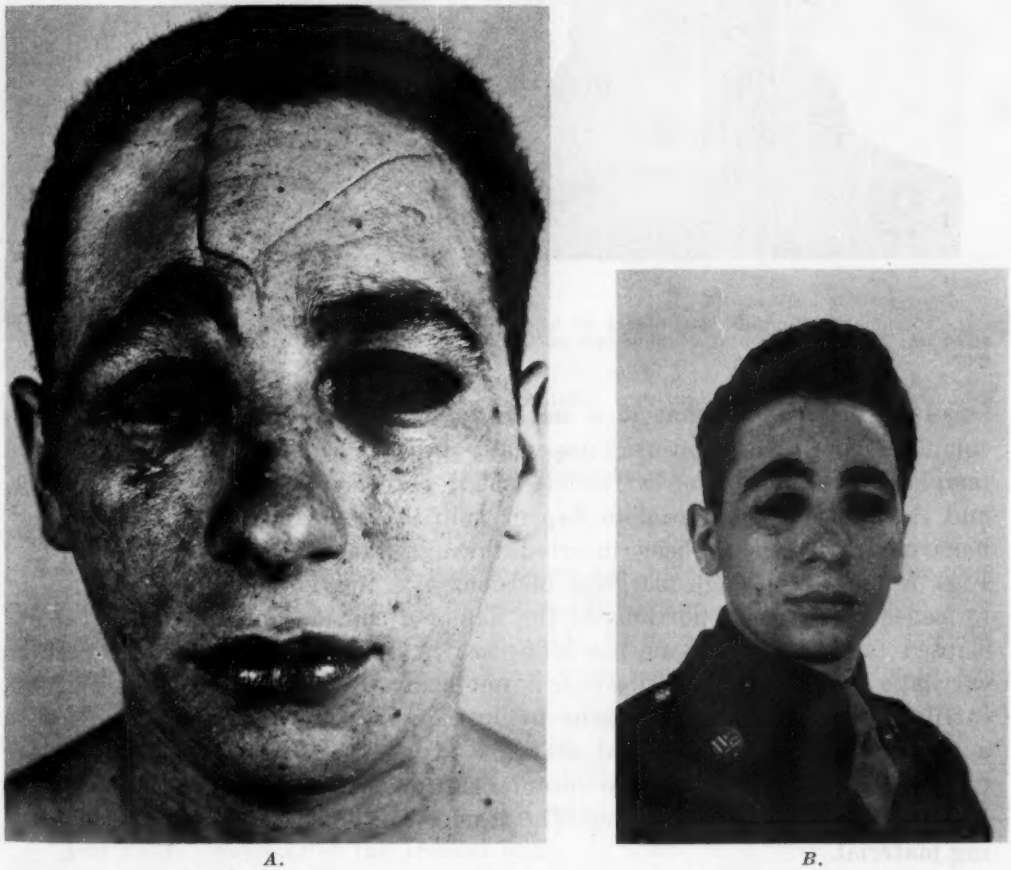
Fig. 2.—*A*, Tantalum cranioplasty with incomplete restoration of right supraorbital ridge. *B*, Roentgenogram showing tantalum plate deficient over right supraorbital ridge. Film reversed during processing.



A. *B.*

Fig. 3.—*A*, Tantalum plate too low laterally over left supraorbital ridge. *B*, Roentgenogram demonstrating lateral distortion of left orbit due to low tantalum plate.

Fig. 4.—Postoperative x-ray view in which the supraorbital ridge was repaired initially with bone and completed later with tantalum.



A. *B.*

Fig. 5.—*A*, Pulsating defect of right squamous portion of frontal bone. *B*, Postoperative right squamous frontal cranioplasty completed with bone through old craniotomy scar.

not result. Conversely, tantalum may be employed secondarily in large defects when bone was used for the initial repair of the supraorbital ridge (see Fig. 4). The tantalum plate was, therefore, removed in each instance noted previously and cranioplasty completed with bone in five instances and revised with tantalum in the remaining three.

A. *B.*

Fig. 6.—*A*, Nonpulsating defect of left squamous portion of frontal bone. *B*, Postoperative left squamous frontal cranioplasty completed with cartilage through previous craniotomy scar.

It is emphasized that it is not always possible or necessary to obtain complete operative exposure,[2] especially if cortical exploration is not contemplated. Such instances include small defects over the frontal regions, and the presence of a remote flap or split-thickness graft. In these cases, bone or cartilage has been inserted through the old craniotomy scar (see Figs. 5 and 6), through marginal incisions of a previous flap (see Fig. 7), or by reflecting varying portions of the flap if a considerable time interval has elapsed (see Fig. 8). Bone has been used in pulsating defects and preserved cartilage in areas where pulsation is not manifested. The tendency of fresh cartilage to curl can be overcome by introducing multiple chips rather than a solid section. The cortical margins of the bone along the defect are rongeured away to expose the vascular surface. When bone is used, it may be taken from the ribs or ilium. The former can be split for additional grafting material.

No form of fixation has proved advantageous as long as a good, firm head dressing is applied and kept in place for twelve to fourteen days. No drains have been employed, the wound being inspected and sutures removed in 3 to 5 days. There is less fluid accumulation beneath the scalp than after the use of tantalum. In the event of postoperative infection, sequestration with loss of part of the graft may take place, but it is unusual to lose the entire transplant under these circumstances.

Fig. 7.

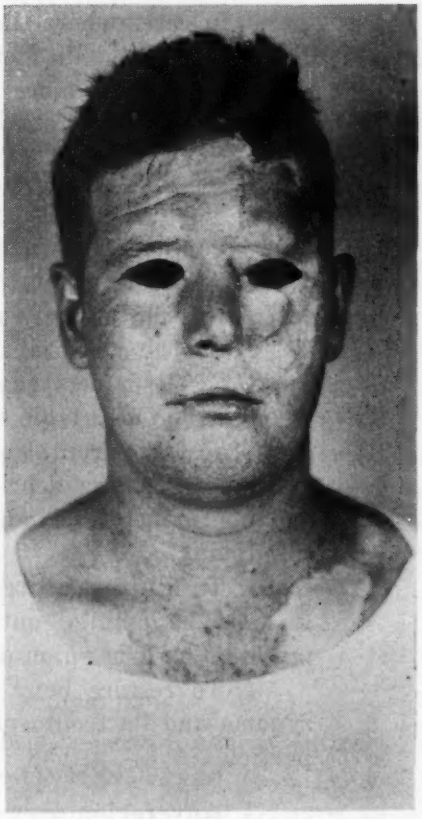


Fig. 8.

Fig. 7.—Postoperative photograph of cranioplasty involving left squamous portion of frontal bone completed with bone which was inserted through marginal incisions to preserve previous remote pedicle flap.

Fig. 8.—Left orbitofrontal wound with associated defect. Completed remote flap in place. Coronal incision with reflection of flap for tantalum cranioplasty ten months later.

SUMMARY

The purpose of this report has been to call attention to three common methods of cranioplasty, namely, tantalum, bone, and cartilage. Each case must be evaluated as to the most suitable form of repair. The various situations in which these materials have been used most satisfactorily are now briefly reviewed.

Use of Bone

1. Small, pulsating defects particularly over the frontal regions including the glabella, supraorbital ridge, frontal sinus, zygomatic and nasal processes of the frontal bone.

2. Small- to moderate-sized defects in any location where only limited exposure can be effected due to possible interference with circulation of a pedicle flap. If extensive, cranioplasty can be performed in multiple stages with bone or started with bone and completed with tantalum corresponding to the amount of exposure possible. The reverse situation is not desirable (bone used in the presence of tantalum) as firm union does not result.

3. Cranial defects in children.

4. In cases where the following may be anticipated: deep x-ray therapy, repeated diathermy to the head and neck, pneumoencephalography in the more severe craniocerebral injuries with dural penetration and likelihood of post-traumatic convulsions.

Use of Cartilage

1. Small, nonpulsating defects over the orbital areas, frontal sinus (particularly when outer wall alone is involved), and nasal processes of the frontal bone. This is important as cartilage does not always unite firmly with bone. Therefore, if previous pulsation was present, it will probably continue.

2. Small defects (nonpulsating) and slight depressed fractures through the outer table of the bone (particularly over the squamous portions of the frontal bone), either in open or closed head injuries in which extensive débridement had not been performed previously and no further late indications exist other than from the cosmetic standpoint.

3. To fill in small residual depressions when bone has been used. It is to be pointed out that this is not done in the presence of tantalum as firm union does not result.

4. To restore bony prominences of the face such as over the zygoma and its frontosphenoidal and temporal processes and orbital portion.

Use of Tantalum

1. Any region over the vertex where complete exposure can be obtained other than in the situations first cited in which cartilage or bone are preferable.

2. Any situation in which bone is contraindicated and complete exposure is possible for fixation: general physical condition of the individual, pre- or coexisting disability.

3. Extremely large defects, for obvious reasons. If long enough time has elapsed in the presence of a remote flap, its reflection should be possible for insertion of such a plate.

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REPAIR OF SCALP DEFECTS

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THE association of extensive craniocerebral and maxillofacial wounds incurred during modern warfare necessitates the close cooperation of both the neurologic and plastic surgeons, not only during the acute reactive phase on the battlefield but also in the period of reconstruction following evacuation to the zone of the interior. Injuries of this type are often accompanied by considerable loss of skin, soft tissue, and bone. The type of incision at débridement is dictated often by the location and severity of the wound or the presence of complications. The procedure should take into consideration the need of later local, direct, or delayed flaps, grafts, cranioplasty, and cortical exploration. The methods employed successfully for scalp revision and closure during the reconstructive period on the neurologic and plastic surgical services at Valley Forge General Hospital may be applied during preliminary treatment behind the front lines, and to similar injuries observed during civil life.

Closure of the scalp following débridement for craniocerebral wounds sustained in overseas theaters was usually accomplished by one or more of the following methods:

1. Approximation of the skin edges.
2. Skin grafting.
3. Advancement of direct, single, or double pedicle flaps.

The use of delayed or remote flaps has been reserved almost entirely for the reconstruction centers in the zone of the interior.

In the majority of patients received here, some form of primary or secondary suture had been performed with or without local rotation of flaps. Many resulted in the formation of thin scalp scars with densely adherent dura and cortex (see Fig. 1). In other cases, the cranial defect had been covered with a free skin graft (see Fig. 2). In still others, the wound was open with exposure of the dura or cortex and with varying degrees of infection. In those with the outer table of the bone alone exposed, an improved bed for grafting was obtained by multiple small perforations to the diploe in order to produce granulations. Patients with open wounds have been treated with hot wet compresses, penicillin (local and systemic), and sulfadiazine as indicated. The simplicity of the definitive treatment depends upon having as few additional scars in the adjacent scalp as possible. Thus, primary repair with skin grafts or primary closure of the wound rather than complicated shifting of flaps has made possible better final repairs. Replacement

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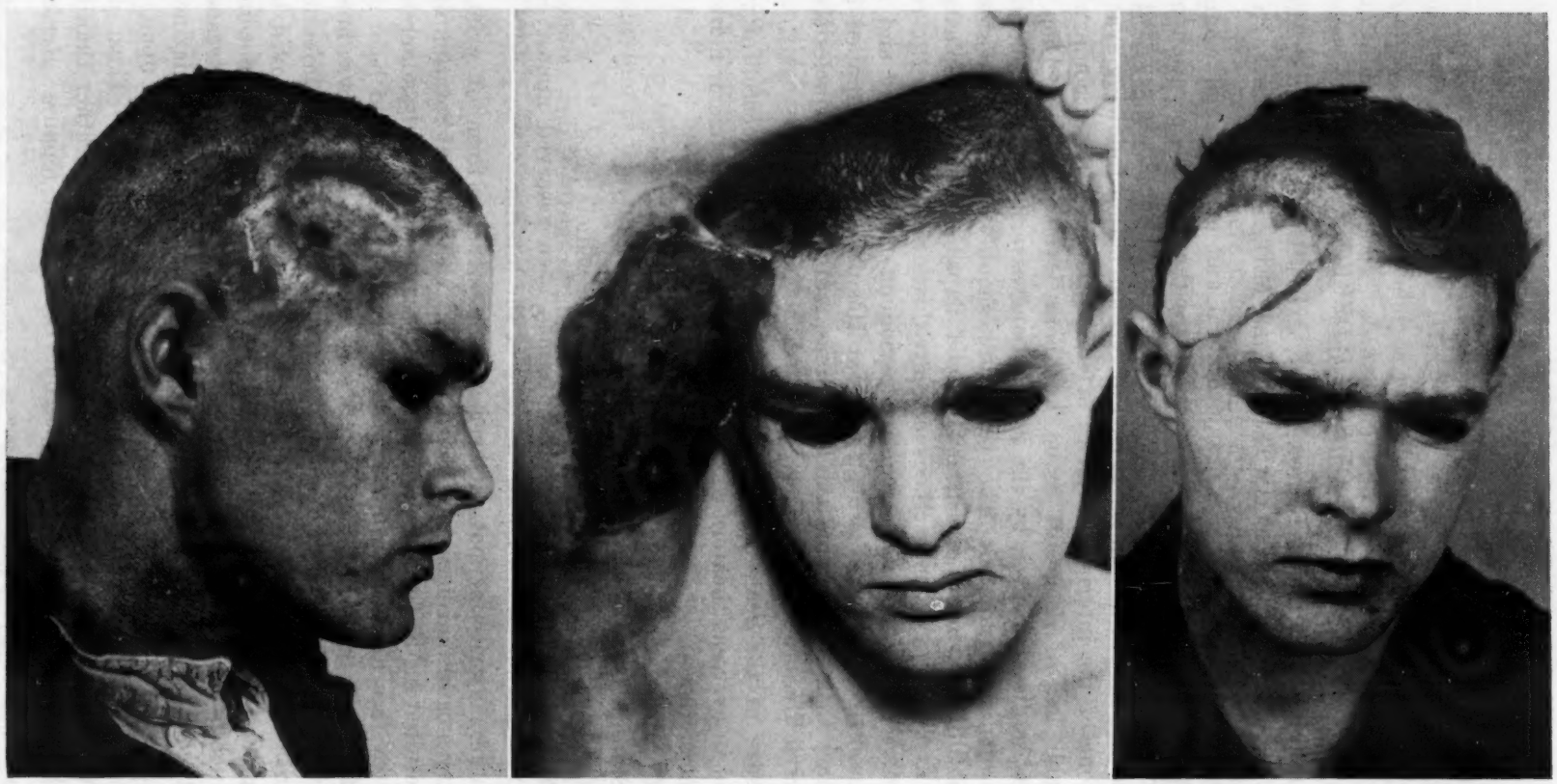

Fig. 1.—*A*, Avulsion wound of right frontoparietal region complicated by brain abscess with residual thin, atrophic scalp scar. *B*, Previously delayed direct flap applied to scalp defect following removal of superficial scar. *C*, Completed flap covering scalp defect prior to cranioplasty.

A.

B.

C.

Fig. 2.—*A*, Extensive left orbitofrontal wound closed with split-thickness graft prior to evacuation. *B*, Previously delayed direct chest flap elevated to involved area following removal of free graft. *C*, Completed pedicle flap prior to cranioplasty.

of thin scalp scars or skin grafts in these cases is necessary for subsequent cranioplasty, dural repair, cortical lysis, or extirpation. The following methods have been used:

1. Excision of narrow craniotomy scars has been satisfactory usually for ordinary cranioplasty and/or cortical exploration. The amount of tension resulting during closure is an important factor for adequate wound healing. A certain amount of stretching of the adjacent tissues and undermining of the margins of the scalp defect is possible. This method, however, has its limitations, as shown in Fig. 3. The majority of patients received here had had repairs done by curvilinear incisions. The tripod incision or its isle-of-man

Fig. 3.—Closure of right frontal incision over tantalum plate elsewhere with distortion of adjacent scalp and brow. Tantalum removed on two occasions due to necrosis and infection. Replacement of soft tissue loss with delayed arm flap.

modification, advised so commonly in World War I, was used rarely due to poor wound healing at the apex of the flaps. A large craniotomy type of flap was employed occasionally. In these circumstances, the wound of entry was included either in the lateral limb of the incision or in its midportion (when small). Previous S- and Z-shaped exposures including the point of entrance in the central limb were encountered also.

2. Coronal incisions are ideal for complete exposure of extensive defects in the frontal region. However, if the scalp scar is either very dense and

A. *B.*

Fig. 4.

Fig. 5.

Fig. 4.—*A*, Left orbitofrontal wound with local frontal pedicle flap to lower lid defect. Frontal scalp repaired with split-thickness graft. Residual midfrontal cranial defect. *B*, Nonpulsating, midfrontal cranial defect repaired with cartilage through old craniotomy scar rather than coronal incision to preserve previously grafted frontal scalp.

Fig. 5.—Patient referred for postoperative infection following tantalum cranioplasty. Wound débrided, plate removed, and closure effected only after a left parietal, relaxing incision was made.

A.

B.

C.

Fig. 6.—*A*, Hair-bearing scalp in left frontal region from previous débridement with advancement of local flap into defect due to gunshot wound. *B*, Cosmetic restoration achieved by rotation of adjacent scalp flap with application of split-thickness graft to previous hair-bearing area. *C*, Patient with previous hair-bearing scalp in left frontal region prior to discharge.

disfiguring or extremely thinned and adherent, primary revision is preferable prior to cranioplasty. Local frontal pedicle flaps from areas with normal underlying bone may be used in the reconstruction of the eyelids and repaired with a split-thickness graft in the presence of a small associated cranial defect. Such a lesion can be repaired easily by entering the previous craniotomy scar and inserting bone if the defect pulsates and by inserting cartilage if no pulsation is present (see Fig. 4). In the larger defects where a coronal incision is planned, other provisions for facial repairs must be made to maintain the integrity of the frontal scalp. A contemplated coronal flap should be delayed if there is any doubt about the blood supply in cases where the previous wounds or operations involved the supraorbital vessels.

3. In the temporal region, there is usually sufficient vascularity to employ the usual craniotomy incision but attention must be directed toward a broad enough unscarred pedicle to insure adequate blood supply.

Fig. 7.—Tubed pedicle flap to right frontotemporoparietal area. Dural repair and application of flap accomplished at one procedure, cranioplasty being performed at a later date. Preliminary surgery was done previously at Cushing General Hospital.

4. Relaxing incisions are useful often in small defects (see Fig. 5). The resulting deficiency of the scalp may be sutured, if possible, allowed to granulate, or be grafted. Exposure of the tantalum plate must be avoided as it will preclude healing.

5. The use of direct, local, single, or double pedicle flaps has its greatest application in the temporal, parietal, and occipital regions. Attention must be directed toward the normal vascular pattern and a wide base is pref-

erable to maintain an adequate blood supply. The advantage of the direct flap is that it can be completed usually in one stage.

6. The use of delayed, remote flaps is indicated particularly in defects of the frontal region where a local hairbearing scalp flap is obviously unsuited (see Fig. 6). Flaps of the latter type were justified during the exigencies of warfare[1] but necessarily must be modified later. Delayed flaps are indicated also in sizable defects which cannot be repaired readily by adjacent scalp tissue.

The undermining of a large remote scalp flap sufficiently to insert and fix a tantalum plate may jeopardize the blood supply, even with good local skin color and without edema, unless a considerable period of time has elapsed (see Fig. 7). If the flap cannot be reflected safely or adequately, bone must be used for the repair instead of tantalum because less exposure is necessary for its insertion. Marginal scars may be entered in approaching the edges of the bony defect. Satisfactory undermining of the flap can be accomplished through these limited incisions. If possible, no new incisions should be made through the flap.

If the color of the skin of the pedicle flap over the forehead and face does not match completely that of the adjacent tissues, tattooing has given very satisfactory cosmetic results.

COMMENT

The securing of an adequate, viable resurfacing of the scalp prior to repair of the bone, dura, or brain cannot be overemphasized because deep surgery can be no more successful than surface healing. In some instances, closure can be accomplished satisfactorily at the time of cranioplasty or craniotomy. In others, preliminary plastic procedures are necessary. If these principles are not observed, postoperative necrosis may occur over the plate, which occasionally can be closed secondarily.* More often, however, infection ensues, the plate is removed, plastic surgery is completed, and the tantalum reinserted at a later date.

SUMMARY

The purpose of this report has been to present the various methods of closure of the scalp. The importance of performing repair of a cranial defect and dura through a good, viable scalp flap has been emphasized because primary healing of the surface wound is essential for successful deep surgery. Repair has been achieved by one or more of the following procedures: revision of previous craniotomy scars, relaxing incisions, occasional coronal or craniotomy flaps, split-thickness grafts, and local and remote flaps.

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*Harris and Woodhall[2] reported one case in which successful repair of a scalp defect was accomplished by preparing and applying a delayed flap in the presence of an exposed tantalum plate (postoperative necrosis of a thin, scalp scar).

CARCINOMA INVOLVING THE COMMON BILE DUCT

Report of Four Cases of Successful Resection

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DESPITE the fact that tumors of the common bile duct produce early symptoms and are supposedly late to develop metastases, the ultimate prognosis is still grave in spite of early surgical intervention. Most of these patients eventually succumb to recurrences of the carcinoma; those who survive, ultimately die as a result of the repeated attacks of cholangitis. The avoidance of ascending liver infection which so commonly follows plastic procedures and reimplantation of the common bile duct is an important problem which is yet to be solved.

This paper primarily is concerned with the report of four patients in whom a carcinoma involving the choledochus was successfully resected. In two instances the tumor was so situated that a segmental resection could be carried out, while in the other two cases it was necessary to perform a duodenopancreatectomy.

One can hardly discuss this interesting subject without presenting some of the associated problems that are involved in such surgical procedures.

Case 1 (Mount Sinai Hospital Admission No. 509762).—Carcinoma involved the junction of the common bile, common hepatic, and cystic ducts. Resection of carcinoma with cystic duct and gall bladder and hepaticoduodenostomy were done. The patient was discharged from the hospital improved.

History.—D. G. was a 71-year-old man who entered the hospital Aug. 24, 1943, complaining of jaundice of four weeks' duration. Family history was irrelevant. Past history disclosed the presence of a mild hypertension for twenty-five years with some recent dyspnea on exertion and a prostatectomy four years previously. Otherwise his general health was good until five weeks prior to admission when he noted an icteric tint to the sclerae, light-colored stools, and a dark-colored urine. The jaundice gradually deepened and with this he noted the onset of postprandial midepigastric oppression and nausea. As the jaundice became worse, a generalized pruritis developed. There was no pain nor vomiting and weight decreased from 175 to 171 pounds.

Physical Examination.—The patient was well developed and nourished, but severely jaundiced. Heart and lungs were normal to auscultation and percussion. The abdomen disclosed a rounded, palpably enlarged mass in the right upper abdomen which moved with respiration. In addition, the liver was distinctly enlarged.

Laboratory Data.—Blood pressure was 150 systolic and 70 diastolic in millimeters of mercury. The urine was acid in reaction, specific gravity 1.010, albumin faint trace, sugar negative, bile strongly positive, and microscopic normal. The hemoglobin was 80 per cent (Sahli); the red blood cells 4,300,000 per cubic millimeter; the white blood cells 7,400 with a normal differential count. The sedimentation rate was 1 hour and 16 minutes. Urea nitrogen of the blood was 8.0 mg. per cent; blood sugar was 115 mg. per cent; and the cholesterol of the blood was 365 mg. per cent; the total proteins of the blood were 5.8 mg.

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per cent. The icteric index at first was 36, but the successive blood tests prior to operation showed a steady rise to 60 and then to 80. The serum phosphatase was 46 King-Armstrong units per 100 c.c. of blood. The prothrombin time was 72 per cent of the normal. The blood Wassermann test was negative and the cephalin flocculation test was negative. A scout roentgenogram of the abdomen failed to show any abnormality and radiography of the colon with a contrast barium enema was normal. The electrocardiogram was also normal.

Provisional Diagnosis.—Diagnosis in this case was considered to be a neoplasm involving the common bile duct or head of the pancreas and was based upon the progressive obstructive icterus with the enlarged gall bladder.

Operation.—Operation was performed Aug. 31, 1943, under general anesthesia. The procedure carried out was a resection of the gall bladder, cystic duct, portions of the common bile and common hepatic ducts, and hepaticoduodenostomy for a carcinoma situated at the junction of the cystic, common hepatic, and common bile ducts.

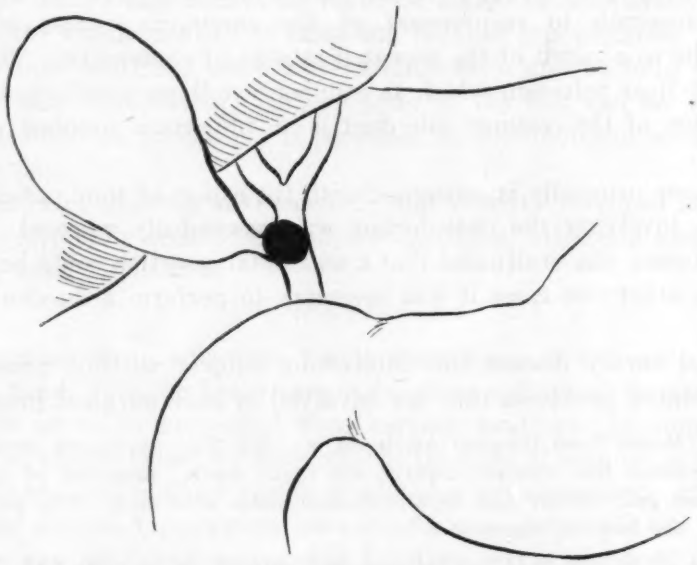

Fig. 1.—Drawing showing relative position of carcinoma in Case 1.

Findings.—There was a fusiform mass about 2.5 cm. in diameter at the confluence of the cystic and common ducts. The distal part of the choledochus was approximately normal in caliber. The common hepatic duct above the tumor was about 1.5 cm. in diameter and contained white bile. The gall bladder was markedly distended with white bile, but did not contain any calculi. There were no lymph nodes palpable in the lesser omentum or portal fissure. The liver was dark green in color and careful palpation of its surface failed to disclose any metastases. The common duct and tumor were intimately adherent to the surrounding structures and a number of dilated vessels were present in the lesser omentum.

Procedure.—A right upper rectus muscle-splitting incision was used. After determining the operability of the lesion, the distal part of the common duct was freed and a temporary loop was thrown around it. The gall bladder was aspirated and emptied completely. It was then freed from the liver bed subserosally and the cystic vessels were ligated with chromic catgut and then cut. The dissection was continued so as to free the cystic duct completely, leaving it and the gall bladder entirely free and hanging attached to the common bile duct and tumor. The common hepatic bile ducts with attached growth were then freed from the surrounding structures in the lesser omentum, ligating the dilated surface vessels with fine plain catgut. The distal part of the choledochus was ligated with No. 2 chromic catgut well behind the duodenum and near the upper border of the pancreas following which it was cut across. The entire specimen was then hanging by the common hepatic duct. It was felt

that end-to-end hepaticocholedochal anastomosis would have to bridge a gap of almost two inches. Therefore, a hepaticoduodenostomy was decided upon. This was done, first, by placing a posterior layer of fine interrupted linen sutures between the hepatic duct and the doudenum. The duodenum and adjacent hepatic duct were then opened and, using two separate 000 chromic sutures, the inner mucosal layer was sutured using a continuous interlocking suture which was tied at each end. The gall bladder, cystic duct, neoplasm, and segments of the hepatic and common bile duct were removed in one piece by cutting through the anterior wall of the hepaticus. A two-inch-long piece of rubber tubing about No. 22 French in caliber was introduced into the anastomosis in such a manner that about one-third of its length extended into the hepatic duct and the remaining two-thirds protruded into the duodenum. It was anchored in this position with a separate, fine chromic catgut suture. The anastomosis was then completed by the use of a continuous inner Connell type of inversion suture for the anterior layer and then the use of fine interrupted linen sutures for the outer layer. The anastomosis was suspended by placing several fine linen sutures between the duodenum and lesser omentum. A rubber dam drain was placed down to the area of anastomosis and the wound was closed with through-and-through heavy silk sutures.

Operative Course.—The operative course was comparatively uneventful with a minimal temperature rise. A mild bronchopneumonia of the left lower lobe responded rapidly to chemotherapy. There was no biliary leakage from the wound. The jaundice disappeared rapidly and by the eighth postoperative day the stools were brown and the icteric index had dropped to 10 and a few days later to 5. He was discharged from the hospital seventeen days after operation. As far as we know the splinting rubber tube had not been passed.

Gross Pathology.—The gall bladder measured 15 by 5 by 3 cm. and to it was attached the cystic and part of the common bile duct. The proximal 4 cm. of cystic duct was markedly dilated. The distal 2 cm. of this duct could not be probed. It was occluded by a firm tumor mass which involved the common bile duct and measured about 2 cm. in length. About 2.5 cm. of common bile duct were attached to the specimen, of which the proximal part measured 1.8 cm. in circumference while the distal part measured 1.3 cm.

Microscopic Diagnosis.—Diagnosis was diffusely infiltrating adenocarcinoma originating at the cystic duct orifice infiltrating the common bile duct and causing stricture; hydrops of the gall bladder.

Follow-up.—The patient was seen about four months after operation and appeared in good health. There was no jaundice and appetite was good. Inquiry two months later disclosed that he had been ill with an episode of chills, fever, and some icterus. A report from the family physician stated that the attacks of chills, fever, and jaundice became more frequent; the patient went downhill and died at home nine months after operation. Whether this patient had a recurrence of the carcinoma cannot be stated because a post-mortem examination was not performed.

CASE 2 (Mount Sinai Hospital Admission No. 523209).—There was a carcinoma of the common bile duct, congenital anomaly of the cystic duct entering the right hepatic duct, and absent common hepatic duct. Resection of gall bladder, cystic, parts of right and left hepatic ducts, and tumor-bearing portion of common bile duct was done. Right and left hepaticoduodenostomies were carried out. The patient was discharged from the hospital improved.

History.—J. L. was a 50-year-old man who entered the hospital July 27, 1944, and was discharged Sept. 11, 1944. Past history was inconsequential. He was perfectly well until about six months prior to admission when he noted the onset of slight nausea and epigastric fullness after meals. Two weeks prior to entry into the hospital he developed some vague upper abdominal pain which was accompanied by jaundice, dark-colored urine, anorexia, and constipation. During this period of time he lost approximately ten pounds in weight.

Physical Examination.—The patient was thin, but showed no signs of emaciation or chronic illness. Skin and sclerae were moderately icteric. Auscultation and percussion of the heart and lungs failed to disclose any abnormality. Palpation of the abdomen

revealed an enlarged liver, the free edge extending for two to three fingerbreaths below the right costal margin. The gall bladder was not definitely felt.

Laboratory Data.—The blood pressure was 124 systolic and 74 diastolic in millimeters of mercury. Urinalysis showed no abnormality except for the presence of bile. The hemoglobin was 77 per cent (Sahli), while the white blood cells were 9,800 per cubic millimeter with a normal differential count. Chemical analyses of the blood disclosed the following in milligram per cent: urea nitrogen 10.0; total blood proteins 6.3, with the albumin fraction 4.8 and the globulin fraction 1.5 cholesterol was 460 of which the esters were 340, but later the cholesterol rose to 1040 with the esters 480. The icteric index was at first 48, but then rose to 60. The galactose tolerance test was normal and the cephalin flocculation test rose from 1+ to 4+. Electrocardiograms of the heart were normal. Guaiac tests of the stools were negative for blood. Roentgenograms of the gastrointestinal tract were normal.

Preoperative Note.—It was felt that this patient had obstructive icterus which was probably caused by a neoplasm of the extrahepatic ducts. Exploratory laparotomy was indicated.

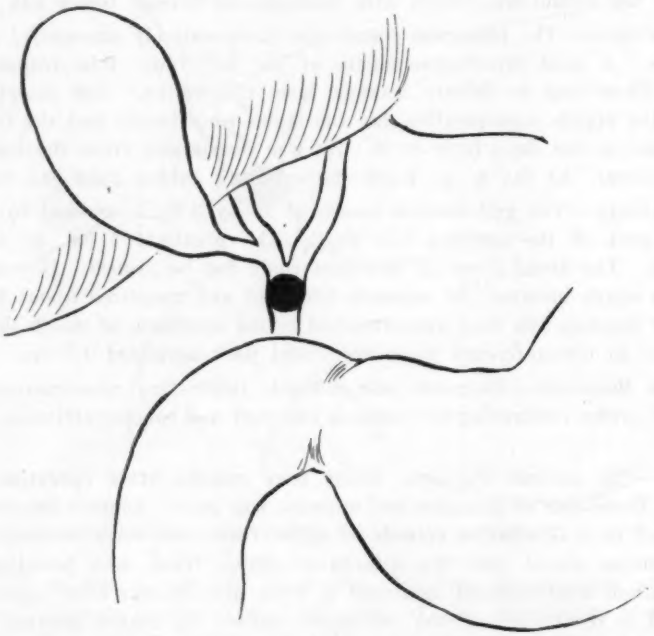

Fig. 2.—Diagram showing relative position of the biliary ducts and carcinoma in Case 2.

Operation.—Operation was performed under ethylene and ether anesthesia on Aug. 10, 1944. The gall bladder was excised, as were the cystic duct, portions of the common bile duct, and right and left hepatic ducts for carcinoma of the common bile duct. Right and left hepatico duodenostomy and complementary jejunostomy for alimentation were done.

Findings.—There were extensive adhesions between the right lobe of the liver and diaphragm which completely obliterated the right subphrenic space. The gall bladder was markedly distended. In the region of the portal fissure a large distended bile duct was visible. It was about 2.5 cm. in diameter and later in the dissection was proved to be a markedly dilated left hepatic duct. About 1 cm. distal to this there was a firm, irregular nodule about 1 cm. in diameter which was thought to be a carcinoma. The second part of the duodenum was situated close to the hilum of the liver. Distal to the nodule, the common bile duct was found to be situated deeply in the lesser omentum, about ¾ cm. in diameter, and covered by a number of dilated venules and bands. The cystic duct emptied into the distal part of the right hepatic duct which was about 1 to 1.25 cm. in diameter. The left hepatic duct was about 2 to 2.5 cm. in diameter. The gall bladder and hepatic ducts were filled with a thick yellow-green bile. The tumor was situated in the common bile duct just

distal to the junction of the right and left hepatic ducts. There were no metastatic nodes in the liver nor in the portal fissure area.

Procedure.—A right upper rectus muscle-splitting incision was used. After opening the peritoneum and dividing the local adhesions, it was felt that the lesion could be resected. The dilated veins and bands overlying the distal common bile duct were doubly ligated with fine plain catgut and divided. The distal choledochus was then freed from its bed and a temporary loop was thrown around it. The gall bladder was then emptied by aspiration and separated from the liver bed subserosally after which the cystic vessels were ligated with No. 2 chromic catgut and cut. The cystic duct was then freed and mobilized to its junction with the right hepatic duct. The distal common bile duct was then doubly ligated with No. 2 chromic catgut and divided. Using the proximal end of the choledochus as a tractor, the rest of the common duct together with the tumor and the right and left hepatic ducts were completely mobilized so that the gall bladder, and cystic and tumor-bearing part of the choledochus were hanging by the two hepatic ducts. Because of the position of the growth and the unusual anomaly of the cystic duct, no other procedure for restitution of the biliary flow was feasible except for a separate right and left hepaticoduodenostomy. This was done by placing several interrupted 000 chromic catgut sutures between the posterior walls of the two hepatic ducts and the second part of the duodenum. The two anastomoses were separated by a distance of almost 1 cm. Following this the posterior walls of the right and left hepatic ducts were cut across transversely and the adjacent parts of the duodenum were opened. A second posterior layer of 000 chromic catgut was then placed in each anastomosis and this suture passed through all the coats of the duodenum and ducts. The specimen was then removed by cutting through the anterior walls of the two hepatic ducts. The two inner layers were completed anteriorly by the use of a Connell inversion suture after placing a No. 20 French-size piece of rubber tubing two inches in length in each anastomosis so that about two-thirds of the tube protruded into the duodenum. These tubes were anchored in position by a separate single fine chromic catgut suture. A second layer of 000 chromic catgut interrupted sutures was then placed between each duct and the duodenum. The anastomosis was supported by placing a few fine sutures between the duodenal wall and the capsule of the adjacent liver.

Because of the two anastomoses, it was considered advisible to do a Stamm-Kader type of jejunostomy about sixteen inches distal to the ligament of Treitz using a No. 16 French whistle-lip catheter. This was brought out through a separate left lateral stab wound. Two rubber dam drains were placed down to the anastomoses and the abdomen was closed in layers with No. 2 chromic catgut and several reinforcing heavy silk sutures which were passed through all the layers of the abdominal wall. The patient was given a transfusion of 500 c.c. of citrated blood during the operation.

Postoperative Course.—Within a few hours after operation, bile was noted in the stomach contents which were aspirated through the indwelling Levine tube. During the first twenty-four hours fluids were administered by a continuous slow drip intravenous infusion of glucose in saline solution. Following this, nutriment, fluids, vitamins, and other substances were given through the jejunostomy tube. The same pabulum mixture was administered through the jejunostomy that has been used on the Service for jejunostomy alimentation in postgastrectomy patients. On the fifth postoperative day some biliary drainage was noted on the dressings, but the wound healed by primary union. On the twenty-first day the temperature rose to 102° F. and this coincided with the cessation of the biliary leak. It was felt that this fever was due to cholangitis and it subsided after several days with the administration of sulfadiazine. A mild secondary anemia was treated with iron preparations and transfusion of citrated blood. The jejunostomy tube was removed on the fourteenth day and all feedings were given orally. On the sixth day after operation the icteric index had dropped to 15 and one week later a test of the icteric index showed it to be 6. The patient was discharged from the hospital Sept. 11, 1944, which was thirty-two days after operation. At this time his weight was 112½ pounds as compared with a preoperative weight of 113 pounds. This maintenance of weight was thought to be the result of early feeding by jejunostomy.

Gross Pathology.—The specimen consisted of a gall bladder with about 1.5 cm. of common bile duct. Attached to the common duct were about 8 mm. of right and left hepatic ducts which were markedly dilated. Immediately below the bifurcation of the hepatic ducts there was a hard mass within the common bile duct which on section revealed a completely encircling grayish-white, soft tumor about 1 cm. in length. The lumen was almost obliterated. The gall bladder was markedly distended with greenish bile, but did not contain calculi. The cystic duct entered the right hepatic duct.

Microscopic Diagnosis.—Diagnosis was adenocarcinoma of the common bile duct and anomalous opening of the cystic duct into the right hepatic duct.

Follow-up Course.—On leaving the hospital the patient was asked to return to the follow-up clinic three months later. He sent a card stating that he was ill with chills and fever. We were unable to examine him at any subsequent time because it was reported that he died at home nine months after operation. Inquiry from the family physician resulted in the information that in the last few months he suffered from recurrent chills, fever, jaundice, and loss of weight. No post-mortem examination was obtained, but the clinical picture suggests recurrent cholangitis with perhaps a return of the original carcinoma.

CASE 3 (Mount Sinai Hospital Admission No. 499047).—There was an adenocarcinoma of the lower end of the common bile duct. Resection of the head of the pancreas, duodenum, and terminal common bile duct and cholecystgastrostomy, gastrojejunostomy, and complimentary jejunostomy were done in one stage.

History.—L. Z. was a 56-year-old, married woman who entered the hospital Dec. 12, 1942, and was discharged on Feb. 18, 1943. She was operated upon Dec. 17, 1942. Past history disclosed that a vaginal plastic operation was done five years previously and that one year before admission she was found on routine examination to have a systolic blood pressure of 160 mm. of mercury and a mild glycosuria. The latter was readily controlled by a dietary regime without the aid of insulin. The illness at the time of admission had begun two months before hospitalization with a generalized pruritus which was followed shortly thereafter by distinct icterus, light-colored stools, and a dark urine. During this period she lost approximately thirty pounds in weight, and noted a sense of fullness in the right hypogastrium.

Physical Examination.—The patient was thin, somewhat emaciated, and slightly icteric. Auscultation and percussion of the heart and lungs failed to disclose any abnormality. The abdomen was scaphoid and in the right upper quadrant the liver could easily be felt extending about two fingerbreadths below the costal margin. In addition, a globular mass interpreted as being a distended gall bladder was also noted. No other abnormal findings were found in the remainder of the physical examination.

Laboratory Data.—Urinalysis was normal except for a trace of bile. The blood count showed a hemoglobin of 90 per cent (Sahli) with normal white blood cell and differential counts. The blood Wassermann test was negative. Chemical analyses of the blood in milligrams per cent showed the following: urea nitrogen 13.0; sugar 100; cholesterol 480 with the ester fraction 300; total proteins 6.2 of which the albumin fraction was 4.3. The icteric index was 5, on the first examination, but then rose to 12. The serum phosphatase (alkaline) was 33 King-Armstrong units and the cephalin flocculation test was negative. Guaiac tests of the stools were negative for blood.

Preoperative Diagnosis.—The enlarged gall bladder and history of jaundice which waxed and waned suggested the possibility of a neoplasm at the ampulla of Vater. Common duct calculus could not be excluded.

Operation.—Exploratory laparotomy was performed* under continuous spinal anesthesia, Dec. 17, 1942. A one-stage operation was done, consisting of a resection of the head of the pancreas, duodenum (first and second parts), and terminal common bile duct with restoration of continuity by a cholecystgastrostomy and a posterior gastrojejunostomy. The pancreatic ducts were ligated and a complimentary jejunostomy was done.

*By Dr. Ralph Colp.

Findings.—The gall bladder and common bile duct were markedly distended with greenish-yellow bile. The liver was distinctly enlarged and icteric in appearance. After partly mobilizing the second portion of the duodenum, a tumor nodule about 1 cm. in diameter was felt behind the duodenum in the general region of the papilla. This mass was considered to be a neoplasm which, because of its mobility and the absence of metastases, was suitable for resection.

Procedure.—A right upper rectus muscle-splitting incision was used. After opening the peritoneum and evaluating the pathology, the gall bladder was emptied by aspiration for a better local exposure. The duodenum and head of the pancreas were mobilized by cutting the peritoneal attachment on the outer border. The common bile duct was isolated in the lesser omentum and a loop was thrown around it. The duodenum was then cut across between clamps at the junction of the second and third portions and the distal end was closed with a double layer of sutures, using 0 chromic for the inner layer and a continuous fine linen suture for the outer layer. The stomach was then cut across just proximal to the pylorus after ligating the right gastric and gastroepiploic vessels with linen ligatures. A retrocolic two-layered gastrojejunostomy was then performed (side-to-side) using a continuous 0 chromic catgut suture for the inner layer, going through all coats of the stomach and jejunum, and

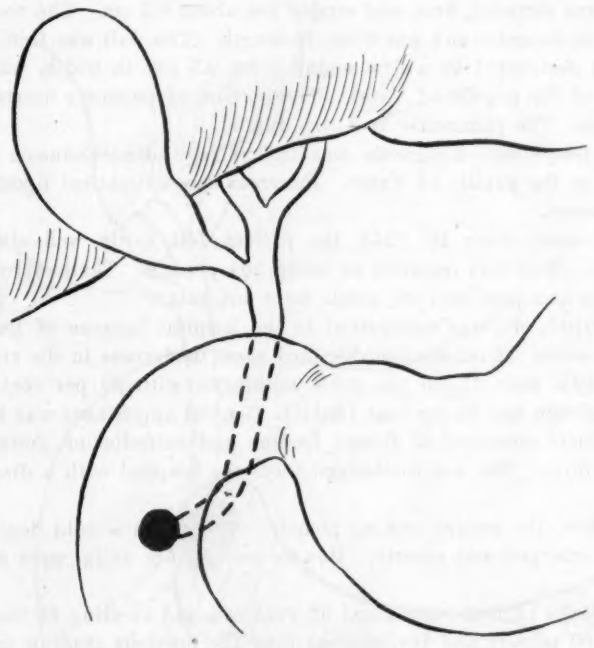

Fig. 3.—Diagram showing position of carcinoma in Case 3.

then using a fine linen suture going through the seromuscular coats for the outer layer. The common bile duct was then doubly ligated with fine linen ligatures and cut across, after which the pancreas was divided between its head and neck identifying the dilated pancreatic duct which was separately ligated with linen. The pancreatic stump was sutured with several interrupted, fine linen stitches. Biliary alimentary flow was re-established by anastomosing the gall bladder with the cut pyloric end of the stomach by means of a two-layered suture anastomosis. About sixteen inches distal to the gastroenterostomy, a Stamm-Kader type of jejunostomy was done using a No. 16 French whistle-lip catheter which was then brought out of the abdomen through a separate left lateral stab incision. The stump of the pancreas was drained with a piece of rubber dam and the abdomen was closed in layers using No. 2 chromic catgut and, in addition, several heavy silk sutures were used to reinforce the wound by passing them through all the layers of the abdominal wall. During the operation, a transfusion of 500 c.c. of citrated blood was administered intravenously by slow drip.

Postoperative Course.—The patient did fairly well after operation. At no time was there any evidence of shock. The highest rise in temperature was up to 102.5° F., which gradually subsided. Intravenous fluids were administereed by drip method for the first twenty-four hours, following which the nutritional and fluid balance were maintained by the feeding of a pabulum mixture and other fluids through the jejunostomy tube. On the tenth postoperative day a pancreatic fistula was in evidence and was proved by the demonstration of diastase enzymes in some of the aspirated fluid. The fistula discharged several hundred cubic centimeters daily and gradually diminished until a complete stoppage occurred about one month after operation. At no time were there any signs of steatorrhea. Just at the time that the pancreatic leakage ceased, a mild biliary fistula appeared which closed spontaneously after fourteen days. The patient was discharged from the hospital Feb. 18, 1943, which was sixty-three days after operation.

Gross Pathology.—Specimen consisted of a resected portion of duodenum together with a portion of common bile duct and a portion of the head of the pancreas. The duodenum measured 8.5 cm. in length and 3 cm. in diameter. The wall was thin and the serosa smooth. The papilla of Vater was located 1.5 cm. from the distal line of resection. The walls of the papilla were considerably thickened and firm in consistency. Just below the papilla, the duodenal mucosa was elevated, firm, and eroded for about 0.5 cm. The common bile duct was dilated to 1.5 cm. in diameter and was 6 cm. in length. The wall was thin. Distally, the common bile duct was obstructed by a firm nodule 1 by 0.5 cm. in width, which was located beneath the mucosa of the papilla of Vater. The portion of pancreas measured 3 cm. in width and 1 cm. in length. The pancreatic duct was dilated.

Microscopic Diagnosis.—Diagnosis was infiltrating adenocarcinoma originating in the common bile duct at the papilla of Vater. Pancreas showed marked lipomatosis and was not involved by carcinoma.

Follow-up Course.—June 16, 1943, the patient felt fairly well although she had not gained any weight. This was recorded as being 104 pounds. There were no chills, fever, or jaundice. Appetite was poor and the stools were not bulky.

October 29, 1943, she was readmitted to the hospital because of loss of weight, chills, fever, and acholic stools. Examination disclosed some tenderness in the right upper abdomen. The white blood cells were 21,700 per cubic millimeter with 90 per cent polymorphonuclear leucocytes. Hemoglobin was 65 per cent (Sahli). General appearance was that of a chronically ill woman. Treatment consisted of forced feeding and sulfadiazine therapy, which caused a subsidence of the fever. She was discharged from the hospital with a diagnosis of ascending cholangitis.

March 15, 1944, the weight was 93 pounds. There was a mild degree of icterus. The liver was notably enlarged and smooth. Bowels moved once daily, were not bulky, and were brown in color.

June 5, 1944, the patient complained of weakness and swelling of the abdomen. Weight was recorded as 100 pounds and the increase over the previous reading was undoubtedly due to the accumulation of fluid in the abdomen and tissues. Paracentesis abdominis was performed, removing 2,500 c.c. of amber-colored ascitic fluid. Examination of this fluid failed to show tumor cells. It was considered that she was probably suffering from a recurrence of the carcinoma with involvement of the portal fissure and portal obstruction.

June 29, 1944, the patient was readmitted to the hospital in a distinctly cachectic state. The abdomen was enlarged and filled with fluid. The sclerae were icteric. After paracentesis of the abdomen was done, the liver was found to be considerably enlarged and nodular. It was obvious that there were multiple metastases to the liver with portal vein obstruction. She gradually went downhill and died July 9, 1944, which was nineteen months after operation. Post-mortem examination was not permitted.

CASE 4 (Mount Sinai Hospital Admission No. 532245).—There was adenocarcinoma of the head of the pancreas with stenosis of the common bile duct. Excision of the pyloric end of the stomach, first, second, and part of the third portion of the duodenum, lower end of the common bile duct and head of the pancreas was done. Restitution of continuity by antecolic

terminolateral gastrojejunostomy and cholecystojejunostomy was carried out, and exclusion of the external pancreatic secretion by ligation of the pancreatic ducts.

History.—J. S., a 59-year-old married woman, was admitted to the hospital March 21, 1945. Past history was irrelevant. She had enjoyed good health until six weeks prior to admission, when she noted for the first time some epigastric fullness and distress after eating some cheese. This was followed by nausea and vomiting which lasted for about twenty-four hours. Shortly thereafter she noted the onset of anorexia, light-colored stools, and a dark urine. Noticeable jaundice then became evident which steadily increased in intensity and was accompanied by a generalized pruritus. During this period she lost twelve pounds in weight.

Physical Examination.—The patient was well developed and nourished and moderately jaundiced. The lungs were normal to auscultation and percussion. The heart was somewhat enlarged to the left and the heart sounds were poor in quality. The blood pressure was 112 systolic and 70 diastolic, measured in millimeters of mercury. The abdomen was obese and palpation disclosed the liver to be enlarged to a point of four fingerbreadths below the right costal margin. In addition, a definite smooth, rounded mass was felt beneath the liver which moved with respiration. This was considered to be a distended gall bladder. Rectal and vaginal examinations disclosed no abnormality.

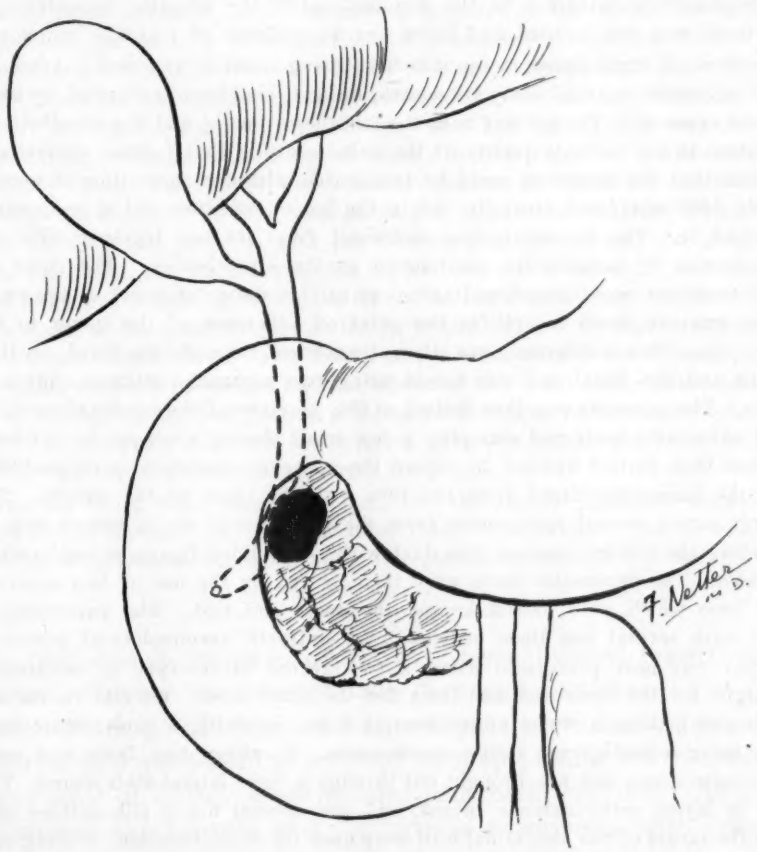

Fig. 4.—Diagram showing position of carcinoma in Case 4.

Laboratory Data.—Urinalysis was normal except for the presence of considerable bile. Chemical analyses of the blood yielded the following results in milligram per cent: urea nitrogen was 8.0; cholestrol was 330 with the ester fraction 225; total proteins were 7.4 with the albumin fraction 4.3 and the globulin component 3.1; icteric index was 30. The blood Wassermann test was negative. A routine roentgenogram of the abdomen was negative except

for the presence of a rounded shadow in the right upper quadrant which was presumed to be an enlarged gall bladder. The electrocardiogram showed evidence of an atypical right bundle branch block and myocardial damage.

Preoperative Diagnosis.—The insidious onset of gradually deepening icterus with an enlarged gall bladder suggested a diagnosis of neoplasm involving the lower end of the common bile duct or head of the pancreas.

Operation.—Operation was performed under ethylene and ether anesthesia on Marcb 26, 1945. Resection of the pyloric end of the stomach; the first, second and part of the third portions of the duodenum, and the head of the pancreas for a neoplasm of the head of the pancreas which obstructed the common bile duct was done. Continuity was restored by an antecolic terminolateral gastrojejunostomy (Polya type) and a cholecystojejunostomy. The pancreatic ducts were ligated.

Findings.—The gall bladder was markedly distended with yellow bile. The liver was enlarged and icteric. There were no metastatic nodules on palpation of its surface. The common bile duct was dilated to approximately 2.5 cm. in diameter. Situated in the upper border of the head of the pancreas was a hard mass about 3 cm. in diameter. The tumor was freely movable, but constricted the pancreatic part of the common bile duct, and on its deep surface was somewhat adherent to the termination of the superior mesenteric vein. The duodenum itself was not invaded and there was no evidence of regional lymph enlargement.

Procedure.—A right upper rectus muscle-splitting incision was used. After opening the peritoneum and exploring the biliary tract area, the gall bladder was emptied by aspiration for a better local exposure. The patient took the anesthesia poorly and the anesthetist constantly called attention to the variable quality of the pulse advising that further operative procedures be planned so that the operation could be terminated within a short time if necessary. The common bile duct was freed from its bed in the lesser omentum and a temporary loop was thrown around it. The duodenum was mobilized from its bed together with part of the adjacent pancreas by incising the peritoneum on its outer border. The right gastric and gastroepiploic vessels were ligated and cut so as to free the pyloric end of the stomach. The mobilization was completed except for the point of adherence of the tumor to the superior mesenteric vein. The duodenum was then transected through its third portion between Payr clamps and the distal end was closed using two separate continuous inversion sutures of fine linen. The pancreas was then incised at the junction of the head and neck, identifying the dilated pancreatic ducts and clamping a few small bleedig areas on its cut surface. The specimen was then turned upward to expose the superior mesenteric vein, and the adherent portion of the tumor was freed from the vein with the point of the scalpel. The stomach was then cut across several centimeters from the pylorus and the specimen was removed by doubly ligating the dilated common bile duct with heavy linen ligatures and cutting the duct distal to them. The pancreatic ducts were then ligated by the use of two separate mattress sutures of linen which were passed around the ducts and tied. The pancreatic stump was then closed with several fine linen stitches. An antecolic terminolateral gastrojejunostomy (Polya type) was next performed using a two-layered suture type of anastomosis with 0 chromic catgut for the inner and fine linen for the outer layer. Several inches distal to the anastomosis and making a stoma approximately 3 cm. in width, a cholecystojejunostomy was done again using a two-layered suture anastomosis. A rubber dam drain was inserted down to the pancreatic stump and was brought out through a right lateral stab wound. The abdomen was closed in layers using chromic catgut, and also several heavy silk sutures which passed through all the layers of the abdominal wall were used for reinforcement. During the operation a continuous infusion of 5 per cent glucose in saline solution was administered intravenously in addition to 500 c.c. of citrated blood. There was no evidence of shock during the procedure.

Postoperative Course.—The postoperative course was reasonably smooth. The highest temperature rise was 101.8° F., which subsided after several days. On the third day after operation, some biliary drainage was noted on the dressings. It was never profuse and stopped completely after five weeks. Stools were definitely brown on the tenth day. Fluids were given intravenously for seventy-two hours, after which nutrition and fluids were given

per os. A mild superficial separation of the wound was noted on the twelfth postoperative day. This was treated by packing, with resultant granulation and subsequent healing. She was discharged from the hospital May 7, 1945, which was forty-two days after operation.

Gross Pathology.—The specimen consisted of the terminal end of the stomach, common bile duct, duodenum, and a portion of pancreas. The pyloric region measured 4.5 cm., and the duodenum 11 cm. in length. Attached were a segment of pancreas measuring 6.5 cm. and 8 cm. of common bile duct. The latter was dilated to a circumference of 3 cm. The portions of stomach and duodenum were normal and the papilla of Vater was likewise normal. Beginning at a point 1.5 cm. from the proximal end of the choledochus, the duct became markedly narrowed and puckered for a distance of 3 cm. by a tumor mass in the pancreas which infiltrated the wall of the common bile duct. This tumor was about 3 cm. in diameter and occupied the portion of the pancreas near the common duct. The undersurface of the pancreas was roughened. A dilated pancreatic duct about ¾ cm. in diameter was identified and could not be probed. Distal to the tumor, the common bile duct appeared normal down to the ampulla of Vater.

Microscopic Diagnosis.—Diagnosis was scirrhus carcinoma of the head of the pancreas with invasion and constriction of the common bile duct.

Follow-up Data.—June 12, 1945, the patient appeared at the office. She appeared somewhat pale and complained of a poor appetite and weakness. Bowels moved once daily, were brown in color, and not bulky. She was advised to go to a convalescent home.

July 23, 1945, she had developed, about one week before, marked weakness, chills, fever up to 105° F., and some jaundice. In addition, there had been a slow decrease in weight. She was readmitted to Mount Sinai Hospital where examination revealed a moderately icteric, pale, chronically ill woman. There was a marked edema of the lower extremities. Fever ranged between 100 and 105° F. The hemoglobin was 51 per cent (Sahli). The total proteins of the blood were 4.1 mg. per cent with the albumin fraction 1.9 and the globulin 2.2 mg. per cent. The cephalin flocculation test was 3 plus, the icteric index 21, and the cholesterol of the blood 260 mg. per cent, of which the ester fraction was 120 mg. per cent. During her stay in the hospital in the succeeding weeks the fever and chills recurred, at no time could it be stated that the administration of sulfadiazine or penicillin altered the clinical picture. The abdomen revealed evidence of ascites and the edema of the lower extremities persisted. This was partly attributed to the low plasma proteins. There was no evidence of metastases in the liver, but this obviously could not be excluded. She was discharged from the hospital on Sept. 1, 1945, with the condition unimproved.

She was not heard from since that time, but the family physician reported that she died at home during the early part of November, 1945. Undoubtedly, the terminal course of events was due to metastases to the liver with repeated cholangitic attacks.

DISCUSSION

In the past decade, renewed efforts have been directed toward eradication of neoplasms involving the common bile duct and pancreas. The difficulties involved in mastering this complicated problem are gradually being overcome by the progressive development of surgical technique and a better understanding of the importance of biliary secretion and pancreatic enzymes. As a result of the many animal experiments and the various experiences with operations in the human being, surgical procedures involving the pancreas and common bile duct are now being done with less timidity, with more success, and with a lower mortality rate than in former years, due in part to the use of vitamin K, antibiotics, the sulfonamide drugs, and the maintenance of electrolytic balance.

Historical Background.—According to Mayo-Robson, the first case of carcinoma of the ampulla of Vater was described by McNeil in 1835, and in 1840

Durand-Fardel described the first case of carcinoma of the common bile duct. Late in the nineteenth century, Von Mering and Minkowski demonstrated that removal of the pancreas in dogs led to the development of diabetes. It was not until 1921 that Banting and Best were able to isolate the acive principle from the pancreas which controlled the sugar metabolism in diabetics.

In the field of surgery we find a report of the removal of a tumor from the body of the pancreas by Trendelenburg in 1882 and mention of the supposed extirpation of the entire pancreas in man by Billroth in 1884. According to Sauvé, resection of the head of the pancreas had been performed at least seven times by 1898. The operation by Codivilla in the same year is of interest. He resected the head of the pancreas, duodenum, pyloric end of the stomach, and, at the same time, re-established continuity by a Roux type of gastroenterostomy and a Murphy button cholecystenterostomy (Trimble and associates). Although his patient died twenty-four days after operation due to cachexia and diabetes, the surgical procedure heralded by many years the operation of today. Also in 1898, Halstead resected a neoplasm involving the papilla of Vater with re-anastomosis of the pancreatic and bile duct to the duodenum. His patient survived for seven months. Apparently Ulizewski in 1902 was the first surgeon to perform a segmental resection of the common bile duct for carcinoma but he failed to re-establish biliary intestinal continuity and his patient died three days later. The following year, Kehr successfully removed a neoplasm of the choledochus and at the same time anastomosed the hepatic duct with the duodenum. His patient survived for twenty-seven months. Sauvé in 1908, as a result of studies on the cadaver, advocated removal of the head of the pancreas by a two-stage operation. The first step called for a gastroenterostomy and for the second stage he advised resection of the second portion of the duodenum, adjacent pancreas, and choledochoenterostomy. He predicted a lower incidence of cholangitis with choledochointestinal anastomoses than in instances where the gall bladder was used. He also advised against pancreaticoenterostomy and advocated drainage of the pancreatic stump. In the recent article by Whipple, Kausch in 1912 "carried out the first successful partial pancreaticoduodenectomy in two stages, implanting the stump of the resected pancreas into the distal end of the resected duodenum. His patient survived for nine months and developed an acute cholangitis. Autopsy revealed no metastases or recurrences." He also mentioned the report of Hirschel in 1914 who performed a resection of part of the duodenum and pancreas, a choledochoduodenostomy, and an implantation of the pancreatic duct with survival of the patient for one year. Likewise, the successful two-stage operation of Tenani in 1922 is quoted. He implanted the stump of the pancreas into the duodenum after resection of an ampullary growth and the patient was well three years after operation. Considerable credit must be given to Whipple for his reawakening an interest in duodenopancreatectomy. With his associates in 1935, a two-stage operation was advocated for removal of ampullary carcinoma with exclusion of the pancreatic secretion. The first successful radical pancreaticoduodenectomy for carcinoma of the pancreas should be credited to Brunschwig in 1937. Three

years later Whipple and, almost simultaneously, Trimble and associates reported the successful results of a one-stage operation and emphasized the advantage of such a procedure.

Numerous modifications have been suggested for duodenopancreatectomy and especially in the treatment of the pancreatic stump and the re-establishment of biliary intestinal continuity. Whipple discarded the earlier suggestion of anastomosis of the gall bladder directly to the stomach or intestine for a choledochojejunostomy of the Roux type. This was to avoid biliary leakage from the ligated common duct stump and to minimize the postoperative incidence of cholangitis. Brunschwig utilized a loop of jejunum for a cholecystojejunostomy with a distal jejunojejunostomy. Trimble implanted the proximal common bile duct into the jejunum through a stab wound in the bowel. Pearse, in his one-stage duodenopancreatectomy, restored the biliary and digestive tract continuity with only two anastomoses, one between the end of the jejunum and the gall bladder and the other between the cut end of the stomach and the more distal side of the jejunum. Cole suggested a Roux type of choledochojejunostomy with the formation of valvelike indentations in the jejunum distal to this anastomosis to prevent reflux of the intestinal contents into the biliary tree.

In the last two cases reported by Child, he performed a duodenopancreatectomy and anastomosed the pancreatic stump with the open end of the jejunum; more distally, sutured the choledochus to the jejunum, end-to-side; and still lower down made an end-to-side gastrojejunostomy. In 1946, Whipple advocated anastomosis of the pancreatic duct with the jejunum through a goiter tube.

Incidence.—As emphasized by Cohen and Colp, tumors of the lower end of the choledochus are intimately related to neoplasms arising from the papilla of Vater and the head of the pancreas. They stated that carcinoma of the ampullary region may arise either from the intestinal epithelium of the papilla, from the termination of Wirsung's duct, or from the mucosa of the lower end of the bile duct. Carcinomas originating from the choledochus in the papillary area are four times as frequent as those developing from the pancreatic duct. It has been generally estimated that common bile duct cancer occurs in from 3 to 3.6 per cent of all patients succumbing to malignancy. Kirschbaum and Kozoll, in 13,300 autopsies at the Cook County Hospital, found 1,808 cases of malignant tumors, of which 62 were due to carcinoma of the bile ducts (3.4 per cent). In another series of 4,239 autopsies at the Glasgow Royal Infirmary, quoted by Pickrell and Blalock, there were 18 instances of cancer of the bile ducts. Renshaw mentioned the series of 4,578 necrospies by Kellynock with only 2 cases of bile duct cancer and also stated that he was able to find 20 instances of primary duct carcinoma in the records of the Mayo Clinic between the years of 1907 and 1921.

The distribution of the primary lesion within the bile ducts is of some interest. Rolliston and McNee in a series of 92 cases of extrahepatic biliary duct carcinoma reported the following: 23 lesions arose in the hepatic ducts; 6 in the cystic duct; 28 at the junction of the cystic, hepatic, and common bile ducts; and

35 in the common bile duct proper. Kirschbaum and Kozoll in their series of 62 cases report: 7 cases in the cystic duct; 13 in the hepatic ducts; 32 in the choledochus; and 10 cases in the papilla of Vater. Marshall's series shows a high incidence of ampullary lesions.

Pickrell and Blalock enumerated 22 instances of resection of the common bile duct for carcinoma. They failed to mention the case of Moschcowitz. Up to 1925, Cohen and Colp were able to collect 58 cases of neoplasms involving the papilla of Vater where surgical removal was carried out. This series of cases was increased to 124 in the report by Hunt in 1941. Between 1935 and April, 1942, Whipple collected 64 cases of radical pancreaticoduodenectomy, of which 23 cases alone were reported within the year preceding 1942. By December, 1944, the same author quoted Orr as having collected 104 cases of radical resections for carcinoma of the ampulla and ampullary region.

These figures serve to indicate that surgeons have lost their timidity in operating for neoplasms involving this hithertofore "untouchable" area.

Pathology.—A classification of the histologic types of carcinoma is given by Kirschbaum and Kozoll in their series of 62 cases.

Common bile duct: The commonest type of tumor was an infiltrating adenocarcinoma. Less common were the papillary adenocarcinoma and the medullary carcinoma.

Papilla of Vater: The majority of the neoplasms were papillary adenocarcinomas, while the other two types were the infiltrating adenocarcinomas and the squamous-cell carcinomas.

The usual cell in these tumors is cylindrical (Renshaw), although spheroidal and mucous cell types can occur. Mucous-producing carcinomas are more frequent in the gall bladder than in the ducts. Squamous-cell neoplasms are obviously the result of metaplasia.

The papillary adenocarcinomas are supposed to result from malignant transformations of a benign polyp. These occur both in the gall bladder as well as in the bile ducts and may be pendunculated. They produce obstruction by projecting into the duct lumen or papilla of Vater in the same mechanical manner that a stone or foreign body may obturate. Essentially, they are as malignant as the infiltrating adenocarcinomas which cause biliary obstruction by the formation of a local stricture. Finally, the biliary flow may be blocked by the pressure of metastatic lymph nodes.

The lymphatic spread of carcinomas of the bile duct may involve (1) the sentinal lymph node at the termination of the cystic duct, (2) lymph nodes in the porta hepatis, (3) periductal, (4) peripancreatic, and (5) periaortic nodes. Metastases may also develop in the liver and more distant areas.

Curiously, metastases from choledochal malignancy are supposed to occur late. Thus, Renshaw quoted Devic and Gallavardin, who found an incidence of 20 per cent in their series of common duct neoplasms. Pickrell and Blalock mentioned the report of Dick who, in 13 autopsied cases of cancer of the choledochus, found no extension of tumor beyond the wall of the duct in 11 cases and no secondary deposits in the lymph nodes. They also quoted the report of

Marshall who found metastases in only 12 out of 49 instances of extrahepatic biliary duct carcinoma. Cohen and Colp stated that in 4 of the cases of papillary cancer that were autopsied at The Mount Sinai Hospital there were no evidences of metastases. The latter authors also quoted Perry and Shaw who noted metastases in only 3 out of 15 instances of papilla carcinoma. On the other hand, Kirschbaum and Kozoll reported an incidence of 76.7 per cent metastatic lesions in their series of 62 autopsied cases of bile duct carcinoma.

In contrast with gall bladder neoplasms, ductal malignancy is less frequently associated with evidences of cholecystitis or cholelithiasis. This undoubtedly explains the high incidence of distended gall bladders in common bile duct neoplasms.

Other associated pathologic lesions may be present. These are largely the result of biliary obstruction and infection. Within the liver one may find biliary cirrhosis, cholangitis, and liver abscesses. Bile peritonitis has resulted from perforation of the gall ducts and bladder or is due to a transudation from the markedly distended and obstructed biliary tree. Ascites can occur as a result of peritoneal implants while occlusion of the pancreatic ducts may cause atrophy of the pancreas and fat necrosis.

Physiologic Alterations.—Tumors involving the common bile duct and adjacent head of the pancreas and duodenum are expected to produce major changes in function. These may be divided into hepatic, pancreatic, and alimentary groups.

Liver.—Interference with biliary flow causes dilatation of the biliary tree and bile radicals of the liver. The resultant icterus and the frequent concomitant infection leads to necrosis of liver lobules and infiltration of the periportal areas with inflammatory cells. The icteric index rises, the Van den Bergh test becomes promptly positive, and the body tissues become stained with biliary pigments. The various liver function tests (bronsulfalein, cephalin flocculation, etc.) show evidence of hepatic impairment. Elimination of bile from the intestinal tract causes light-colored stools and poor fat absorption from the bowel. Distention of the biliary tree may cause not only a loss of appetite but pain which varied from mild epigastric distress and nausea to severe biliary colic.

Pancreas.—Obstruction of the external pancreatic secretions implies complete occlusion of Wirsung's duct and the accessory duct of Santorini. The average amount of pancreatic juice which enters the intestine varies from 500 to 800 c.c. daily. In one case of external pancreatic fistula due to a pancreatic cyst, over 1,770 c.c. were recovered in twenty-four hours (Miller and Wiper). Since this patient's stools and intestinal digestion were undisturbed, it must be assumed that some pancreatic juice must have entered the intestine. The external secretion of the pancreas contains the proteolytic enzyme trypsinogen which is activated by the intestinal enterokinase, the carbohydrate-splitting enzyme amylase, and the fat-splitting enzyme lipase which is enhanced in action by the presence of bile. Obstruction of the pancreatic ducts by a neoplasm should lead to loss of enzymatic action and intestinal digestion. This theoretical expectation has not been borne out in the studies of patients who were subjected

to duodenopancreatectomy with exclusion of the pancreas. Thus, in two of Whipple's cases, about 85 to 90 per cent of the ingested fat was absorbed. He suggested the possibility of an additional fat-splitting enzyme in the intestine. It is also possible that some physiologic adjustment has occurred in these patients because a certain amount of acinar atrophy within the pancreas had already taken place prior to operation.

One may mention that even those patients who were subjected to total pancreatectomy do not necessarily exhibit alterations in food digestion, although these cases develop diabetes.

Considerable discussion has arisen regarding the relationship of loss of external pancreatic secretion and the development of fatty infiltration of the liver and a lowered blood lipid content. Animal experimentation with ligation of the pancreatic ducts, and complete depancreatization in dogs maintained on an adequate diet and insulin have shown the following: (1) The fat content of the liver increases 20 or more per cent. This is not evenly distributed throughout the liver and does not occur until twelve to twenty-four weeks after operation. (2) The blood lipid level drops and the esterized cholesterol fraction may disappear. (Montgomery, Entenman, Chaikoff, Kaplan, Allan, Bowie, MacLeod, and others). These effects are not related to the amount of fat intake (Bloor). The ingestion of fresh pancreatic juice, raw pancreas, lecithin, choline, and lipocaic as suggested by Dragstedt prevents the lowered blood lipids and fatty liver. Also, the administration of these factors will reverse the fatty changes in the liver. It has also been shown that if depancreatized dogs live long enough, there is a spontaneous regression of the fatty liver. Although Dragstedt suggested lipocaic as an internal secretion or hormone of the pancreas, various experimenters have brought evidence in apparent contradiction.

From a practical standpoint it can be stated that some patients in whom the external pancreatic secretions are excluded will tolerate and digest food and fats well while others derive benefit from lipocaic and adjuvant pancreatic extracts. The experimental work in dogs has not been completely borne out in man regarding the effects of total pancreatectomy and exclusion of the external pancreatic secretions. Fatty infiltration of the liver was found at autopsy in 10 out of 52 cases of carcinoma of the pancreas and ampulla by Schnedorf and Orr. The blood lipids in man have not been altered in some of the cases of total pancreatectomy and occlusion of the external pancreatic secretions. Perhaps the diet contained adequate amounts of lipocaic or lecithin.

Alimentary.—Duodenal obstruction can occur in neoplasms involving the head of the pancreas. In such instances the clinical picture is similar to that of pyloric obstruction with the evidences of vomiting, loss of appetite and weight, loss of chlorides, and its secondary effects. Radiography of the stomach and duodenum may reveal distention of the duodenum and stomach, while on occasions, the duodenal curve is distinctly widened.

Clinical Features.—Many of the clinical features have already been mentioned. The classical clinical picture of carcinoma of the choledochus or papilla or adjacent head of the pancreas is generally characterized by a progressively

deepening and painless jaundice which is associated with an enlarged and palpable gall bladder. Symptoms usually appear early due to the strategic location of the neoplasm. The history is frequently of short duration. Pain may vary from a dull epigastric distress to severe biliary colic. The icterus is progressive and the stools become acholic. In the group of 222 cases studied by Lieber, Stewart, and Lund, jaundice was present in all but four of the patients. Melena is uncommon and may result from ulceration of a carcinoma of the ampulla. Icterus which subsides and is accompanied by blood in the stools suggests the presence of a papilla malignancy. Loss of weight is common and is probably attributable to the loss of appetite and gastrointestinal disturbance. Nausea and vomiting are frequent. The onset of fever may signify cholangitis. Anemia occurs in about 30 per cent of the cases (Kirschbaum and Kozoll). An enlarged gall bladder in carcinoma of the bile duct and adjacent area is more often found at autopsy and operation than by abdominal palpation. Courvoisier stated that a distended gall bladder occurs in 84 per cent of duct cancer, while in the studies of Kirschbaum and Kozoll it is nearer to 60 per cent. Biliary peritonitis has already been mentioned. Ascites occurs with peritoneal metastases. Roentgen examinations may show a widening of the duodenal curve or a duodenal obstruction in patients with pancreatic carcinoma. In rare instances, neoplasms of the common bile duct, papilla, and pancreas may be silent and are incidental findings at autopsy.

Prognosis.—The outlook for patients with malignancy of the common bile duct, papilla of Vater, and head of the pancreas is very grave. As a result of the deep jaundice, cholemia, cholangitis, cachexia, metastases, and other complications, patients unoperated upon die rapidly after the onset of symptoms. "Ninety-seven of one hundred patients not subjected to surgery lived two weeks to twenty-eight months and of these 80 per cent died before twelve months." (Lieber and associates, for carcinoma of peripapillary area.) Death occurs in from two to ten months after the onset of progressive jaundice in patients with carcinoma of the pancreas. (Schnedorf and Orr).

Palliative operations aim at relieving the jaundice and pruritus but carry a high operative mortality and stave off death for a short time.

Despite the morbidity and operative mortality, radical extirpation of the malignant tumor offers the only hope for cure. In the series of 124 cases of ampullary tumors reported by Hunt in 1941, 93 patients were treated by transduodenal excision; 5 patients were treated by retroduodenal removal; 11 patients were treated by resection of the duodenum with end-to-end anastomosis of the intestine and implantation of the ducts; and 15 patients were treated by some form of resection of the duodenum and pancreas. In this group of patients about 14 per cent of those surviving operation lived from three to twenty-two years after operation. Pickrell and Blalock's report of segmental resection of choledochal carcinoma disclosed that of 14 patients who survived operation and were followed postoperatively, at least 4 lived for more than eighteen months. Garlock's patient lived for five years after operation but finally succumbed to metastases. As yet, it is difficult to evaluate the late results and prognosis in

patients who were subjected to duodenopancreatectomy for carcinoma of the papilla or head of the pancreas. However, several patients have lived for more than two years.

The immediate operative mortality may be best summarized as shown in Table I.

TABLE I

	PER CENT
Pickrell and Blalock for suprapapillary tumors	22.7
Hunt for ampullary lesions	
1898 to 1925 (58 cases, series of Cohen and Colp)	41.3
1925 to 1941 (66 cases)	21.2
Whipple for duodenopancreatectomy, 41 cases (two-stage operation)	29.2
Whipple for duodenopancreatectomy, 23 cases (one-stage operation)	34.7

The prognosis after operation is largely dependent upon recurrence of the carcinoma with metastases and the occurrence of cholangitis. The latter complication is of serious moment and has not as yet been overcome. All patients who are subjected to resection of a choledochal or periampullary carcinoma require some form of biliary intestinal restitution. End-to-end suture of the common bile duct frequently leads to stricture formation, biliary stagnation, and infection. The use of splinting tubes for the anastomosis, whether made of rubber or vitallium, may result in late incrustation of the tube and bile blockade (Bettman and Tannenbaum, Colp). The incidence of cholangitis is greater in cases where the common or hepatic ducts are reimplanted into the gastrointestinal tract. This obviously removes the normal sphincter mechanism at the papilla of Vater. Such reimplantations are an absolute necessity in duodenopancreatectomy. Bracken and David mentioned the following statements relative to anastomosis of the bile ducts to the gastrointestinal tract.

Gage: In 40 dogs subjected to choledochoduodenostomy the liver showed histologically small abscesses and necrosis.

Sandblom, Bergh, and Ivy: The site of anastomosis does not affect the problem of ascending liver infection.

Bernhard: After anastomosis of the gall bladder to the gastrointestinal tract, barium regurgitates into the liver.

Wilde Gans: Observed numerous cases of barium in the liver after choledochoduodenostomy.

Lahey. The majority of cases with rubber tubes in the new anastomosis develop chills, fever, and jaundice.

Judd: In 47 cases of hepaticoduodenostomy, contracture of the anastomosis developed in 7 cases.

Ladd and Gross: Nine patients were well for from five to sixteen years after operations for stricture and atresia of the biliary tract.

Eliot: In 1936 collected 56 cases of hepaticoduodenostomy and found 11 patients well after ten to twenty years. Cholangitis was common.

Walters: In 1939 reported a series of 80 cases operated upon for benign stricture of the biliary ducts with good results in 68 per cent.

It has been stated that a large stoma in the new anastomosis leads to regurgitation into the biliary tree while a small stoma has a tendency to stenose. In an effort to minimize the incidence of cholangitis, various suggestions have been made for biliary intestinal anastomosis after duodenopancreatectomy. Whipple advised against the use of the gall bladder for the anastomosis and considered the stomach an inadvisable site because of the strong muscular wall.

Trimble implanted the stump of the choledochus obliquely into the jejunum through a stab incision in the bowel. The method of Cole and his co-workers of making a valvelike arrangement in the blind loop of the Y to which the common duct is anastomosed has already been mentioned. Bracken and David advocated the use of a cutting suture to unite the bile duct and bowel. It appears logical that a Roux type of bile duct to intestinal anastomosis may minimize the incidence of cholangitis and it would be wise to perform the gastrointestinal anastomosis distal to the biliary intestinal anastomosis.

The problem of postoperative cholangitis is one that is yet to be solved.

Treatment.—It is not the scope of this presentation to describe the infinite details which are involved in operations for the removal of malignant tumors involving the choledochus, periampullary region, or head of the pancreas. The technique has already been well described (Whipple, Hunt, Brunschwig, and others). The present consensus favors a one-stage operation. It should be planned in such a manner that the procedure can be terminated within a short time for a staged operation if the condition of the patient warrants early termination of the operation. Careful preoperative preparation with fluids, plasma, whole blood, and vitamin K are necessary. The anesthesia must be chosen carefully, for the procedure is time consuming. Continuous spinal anesthesia is of great help. An adequate supply of whole blood during the operation is advisable to combat shock and blood loss. A complementary jejunostomy for feeding is suggested for use in some cases, as an aid in the early convalescent period. Biliary and pancreatic leaks are frequent and troublesome so that adequate drainage is necessary. The prophylactic use of penicillin may be of value in the prevention of infection.

CONCLUSIONS

1. Two cases of segmental resection of the common bile duct for cancer were presented. In one case, a rare anomaly of the biliary ducts necessitated a separate anastomosis of each hepatic duct with the duodenum. Both patients survived operation.

2. Two cases were presented of one-stage duodenopancreatectomy. In one patient the neoplasm involved the lower end of the common bile duct, while in the other the tumor was situated in the head of the pancreas.

3. A discussion of the historical features, incidence, and pathology of choledochal neoplasms was presented.

4. The problem of cholangitis which follows operations for stricture of the common bile duct or biliary intestinal anastomosis is yet to be mastered.

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PERFORATION OF THE SMALL INTESTINE BY THE MILLER-ABBOTT TUBE

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ACCIDENTS and complications have been reported with the use of the Miller-Abbott tube. However, in reviewing the literature, we have failed to note a single case of perforation of the small bowel during intestinal intubation. It is the purpose of this communication to point out some of the dangers involved in the procedure of intestinal decompression by intubation, and to present a case report of small bowel perforation by the Miller-Abbott tube.

Before considering the dangers associated with intestinal intubation in bowel obstruction, it is logical to review the indications and contraindications of this procedure.

Twelve years have elapsed since Miller and Abbott[1] first advocated the use of the double-lumen balloon-tipped tube for the control of distention in the obstructed intestine; eight years of clinical experience following its first reported application by Abbott and Johnston[2] in 1938 have demonstrated definite indications for, as well as contraindications to, its use.

Wangensteen[3] and Dearing[4] have classified the intestinal obstructions into three major clinical groups and have indicated the role of intubation in each category:

Obstructions Suitable to Treatment by Intubation Alone.—The first group includes cases of paralytic or adynamic ileus where there is considerable distention of the intestine without mechanical factors. This may be produced reflexly by trauma, especially to the spine, by ureteral colic, etc., or the ileus may result from an intraperitoneal inflammatory process, for example, primary hematogenous peritonitis. In such cases intubation often lessens distention so that surgical intervention for the relief of distention per se is unnecessary.

Obstructions Where Intubation Is a Preoperative Adjunct.—The second group includes the various types of mechanical obstructions in their early stages. The obstruction may be the result of extraluminary, intramural, or intraluminary causes. As a rule, decompression of the distended intestines under these circumstances is a preliminary procedure designed to facilitate subsequent surgical intervention.

Obstruction Where Intubation Is Utilized Postoperatively.—Most cases of immediate postoperative abdominal distention are relieved by suction via a single lumen (Levine) tube. However, there are occasional cases in which the distention persists, because it results from the presence of early postoperative fibrinous adhesions. It is felt by many surgeons that the absorption of these adhesions is enhanced by the use of the Miller-Abbott tube.

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The Miller-Abbott tube is especially useful in that group of cases in which circulatory changes (strangulation) in the bowel require immediate surgical intervention. In this category, postoperative intubation is a valuable adjunct in preventing further distention and in contributing to the restoration of normal intestinal tone and function.

Postoperative intubation is also of value in relieving tension on suture lines following elective intestinal resections and anastomoses.

Lest this classification be considered as indicating the desirability of intestinal suction in all cases of obstruction, the contraindications should also be emphasized. When there is a reasonable possibility of vascular strangulation of the bowel, intubation should not be attempted except as a preparation for immediate operation. The danger is that although decompression offers no beneficial relief in vascular obstruction, it may in fact mask the symptoms to such an extent as to minimize the urgency of operation which is the essential therapy for intestinal strangulation. The decision for immediate surgery depends upon all the available clinical facts at hand, and if strangulation cannot be ruled out, surgery is indicated. Willson and others have shown that intestinal suction should not be resorted to in cases of obstruction of the large bowel which show great distention of the colon and little or no evidence of small bowel involvement. In these cases of so-called closed loop obstruction of the colon, the ileocecal valve is still competent and does not permit the pressure within the large bowel to be relieved by regurgitation into the ileum. Accordingly, intestinal intubation is not the treatment of choice because the relief of pressure in the large bowel may be unwisely delayed.

Complications.—Although its advantages are unquestioned, intestinal intubation if used unwisely may lead to serious and even fatal complications. In the employment of an indwelling tube for the relief of intestinal distention, it is of great importance that the surgeon remember that this therapeutic method, like many others, produces a combination of desirable and undesirable results, and in any particular case the indications for its use must be such that the advantages far outweigh the disadvantages. It is, therefore, worth while to point out some of the undesirable effects and complications which may occur during continuous suction drainage of the intestinal tract with the Miller-Abbott tube.

Murphy,[5] Brooks,[6] Romano,[7] Wangensteen,[8] and Taylor[9] have discussed in considerable detail the physiologic changes and the fluid, electrolyte, and mineral imbalances which occur as a result of the continuous withdrawal of intestinal contents by means of suction drainage. They have also indicated the importance of, and the methods of, adequate replacement therapy, so that these factors will not be reviewed here.

It is important, however, to emphasize some of the other complications which occur specifically as a result of the presence of the tube itself within the gastrointestinal tract:

The problem of how long intubation may be used with impunity arises. Although in the average case suction-intubation usually accomplishes its purpose in one to three days, occasionally distention may persist to such a degree

and for so long as to require continuous drainage over a period of many days or even weeks. Herein lies another danger of the procedure. It must be remembered that the tube may incite a reaction anywhere along its course in the gastrointestinal tract. Several illustrations of involvement of the nasopharynx, larynx, esophagus, and stomach have been reported in the literature. Vinson[10] cited three cases of esophageal stricture resulting from prolonged intubation following abdominal operations. All three patients recovered, although the ensuing strictures necessitated repeated dilatations in each case. Iglauer and Molt[11] have discussed the possibility of permanent injury to the larynx. They reported ten cases of laryngeal edema produced by indwelling tubes, in eight of which tracheotomy was necessary. In their group of cases the tube was retained in place for periods varying from six to twenty days. They observed that the symptoms were gradual in onset, usually occurring after the tube had been permanently removed, and increasing until tracheotomy became imperative. Two cases came to autopsy: one showed deep ulceration of the upper end of the esophagus; the other exhibited shallow linear ulcers in the upper esophagus associated with marked laryngeal inflammation. These authors stressed the fact that laryngeal edema, although severe, may escape notice in an extremely ill patient. In one of their cases, the patient, while unconscious, was fed through a Levine tube for five days. The obstruction resulting from the laryngeal edema did not become apparent until consciousness returned. Kaufman and associates[12] reported a case of laryngeal edema in a patient who was receiving Miller-Abbott intubation. Although the edema was relieved by tracheotomy the patient died three days later. At autopsy the larynx was edematous and the mucosa of the trachea was intensely congested and covered by a fibrinopurulent exudate. Death was attributed to toxemia, inasmuch as the patient was also suffering from several organic diseases.

Two cases of injury to the arytenoid cartilages[8] following prolonged intubation were reported by Wangensteen in 1939. In one of these cases the patient required a tracheotomy and was left with some permanent limitation of motion in one of the vocal cords. In the other case the edema subsided after drainage of an abscess.

Morrison,[13] in his textbook of otorhinolaryngology, also referred to cases of laryngeal injury from the wearing of a duodenal tube. He stated that "cricoid chondritis may occur when a rubber feeding tube has been retained in the esophagus for long periods."

Mahon,[14] in a paper which reviews some of the pertinent literature, reported a case of multiple perforations of the stomach with peritonitis, following Levine tube drainage. This patient required Levine tube suction drainage for a period of one week postoperatively following a partial small bowel resection for acute intestinal obstruction. Two days after removal of the tube the patient developed severe dyspnea necessitating an emergency tracheotomy. This afforded transient relief but the patient died ten hours later. Autopsy revealed four areas of necrosis on the anterior wall of the stomach just above the greater curvature. Perforations had occurred through two of these, presumably by pressure

necrosis. Death was attributed to peritonitis following perforation of the anterior stomach wall, plus massive atelectasis of the lungs.

Although a review of the literature failed to reveal any reports of a similar accident, it has been stated by Wangensteen[8] that upon inquiry of various pathologists in Minneapolis and St. Paul he learned that an occasional small erosion of the gastric mucosa had been observed following the use of various gastrointestinal tubes.

Mahon also cited Glassman[15] and Wolf,[16] who have reported series of cases of rupture of the stomach. "In some of these the accident occurred during lavage for an obstructive pyloric lesion; in others during intubation for removal of fluid and gas from an overfilled stomach." The outcome in most of these was usually fatal.

Finally, Lemmon and Paschal[17] described a case in which the patient also died from rupture of the stomach. The fatality in that case was attributed to a delay in operating while awaiting improvement by intubation and parenteral fluid administration.

The following case report is presented to illustrate another type of complication resulting from the use of the Miller-Abbott tube, which, to our knowledge, has not been previously reported.

CASE REPORT

P. C., a 40-year-old married woman was first admitted to the Jewish Hospital of Brooklyn on March 25, 1944, complaining of a mass in the right abdomen associated with intermittent pain for five months. The mass was palpable by the patient in the right hypochondrium, and the pain, which gradually increased in severity, was always referred to the right upper quadrant. There was no history of weight loss, melena, or change in bowel habits. A work-up, which included intravenous urography, a gastrointestinal series, and a barium enema, revealed the presence of a carcinoma of the colon in the region of the hepatic flexure. The patient also exhibited evidence of a moderate secondary anemia. Five days of preoperative preparation were given. During this period, the hemoglobin was improved with two blood transfusions, a positive nitrogen balance was obtained by the administration of daily parenteral amino acid preparations, and the liver was fortified with intravenous glucose and vitamins. In addition, a reduction in the bacterial (coliform) flora of the intestinal tract was accomplished by giving the patient sulfasuxidine (succinylsulfathiazole) orally.

The patient underwent a laparotomy on April 18, 1944. As suspected, an annular tumor of the hepatic flexure was encountered. A right hemicolectomy was performed with immediate aseptic anastomosis over Furniss clamps (end-to-side ileotransverse colostomy). The microscopic pathologic diagnosis was adenocarcinoma. The postoperative course was uneventful, and the patient was discharged on May 8, 1944, the twentieth postoperative day. She returned to work in July, 1944, and remained free from symptoms. In October, 1945, a checkup barium enema revealed no unusual findings. The anastomosis was patent and functioned properly.

On April 1, 1946, two years after the colectomy, the patient experienced a sudden onset of sharp epigastric pain which radiated along both costal margins. It was severe enough to require frequent injections of morphine during the next four days. Associated with the pain there was nausea, vomiting, and gradually increasing abdominal distention. The patient did not have a bowel movement following the onset of the pain, but she was able to pass small quantities of flatus per rectum.

She was readmitted to the Jewish Hospital of Brooklyn on April 5, 1946, on the fourth day of the illness. The patient appeared markedly dehydrated. The abdomen was dis-

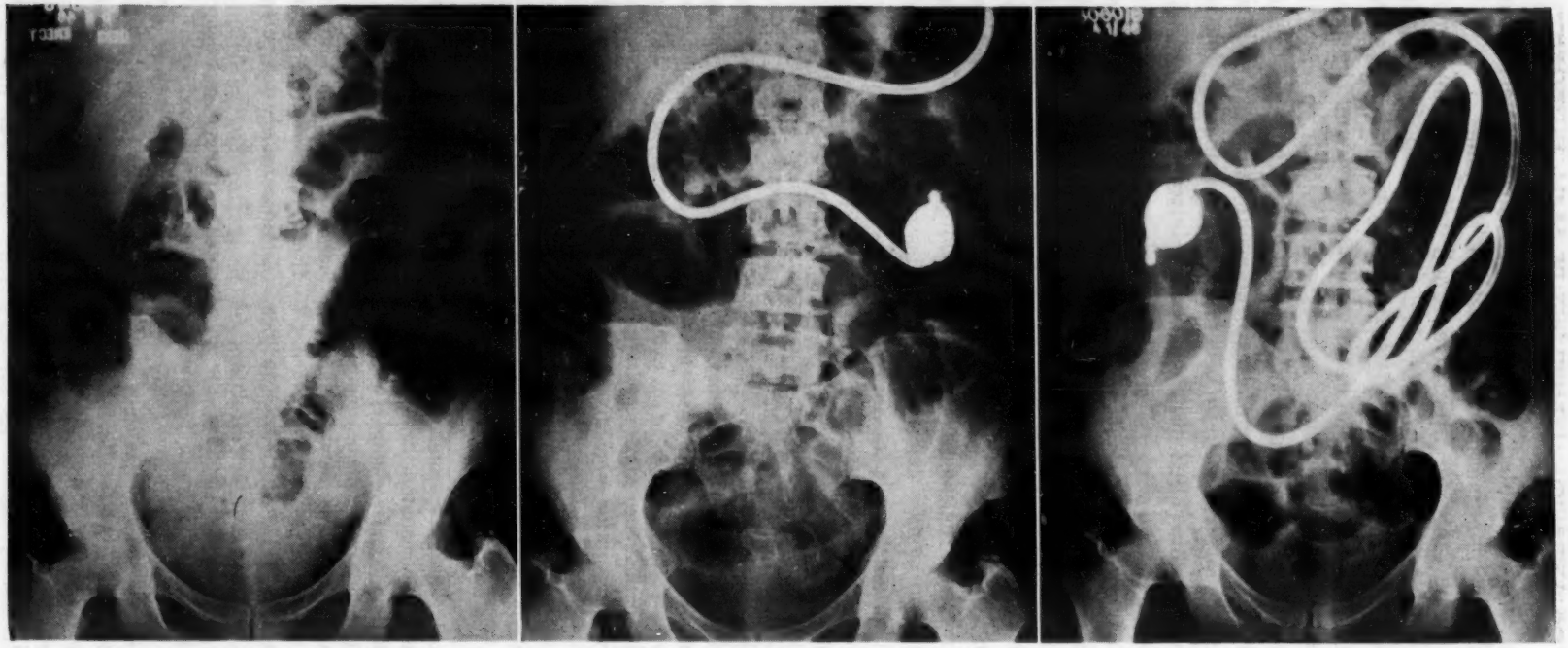

Fig. 1. Fig. 2. Fig. 3.

Fig. 1.—A scout film of the abdomen, revealing diffuse distention of both large and small bowel loops.
Fig. 2.—Diminution in the degree of intestinal distention, resulting from Miller-Abbott intubation.
Fig. 3.—Same as Fig. 2; the tip of the tube is now located in the right upper quadrant.

tended and tympanitic. A scout film of the abdomen revealed diffuse distention of both large and small bowel loops (Fig. 1). There was no clinical evidence of circulatory embarrassment of any bowel segments. The patient's nitrogen fluid and electrolyte balance was restored with continuous parenteral administration of glucose, saline, and protein solutions. A Miller-Abbott tube was introduced on April 6, 1946, and attached to a Wangensteen continuous suction apparatus. The tube passed the pylorus and entered the duodenum without any unusual delay. It then progressed down through the jejunum to the ileum. Considerable amounts of small intestinal fluid contents were removed by the suction drainage, and as the tube progressed the abdominal distention diminished (see Figs. 2 and 3). On April 11, 1946, a scout film (Fig. 3) revealed the tip of the tube in the right upper quadrant. At no time did the tube progress beyond this point. Repeated attempts to facilitate further passage were made by withdrawing the tube for a distance of eighteen inches and permitting it to progress again. After each partial withdrawal, the abdominal distention and pain

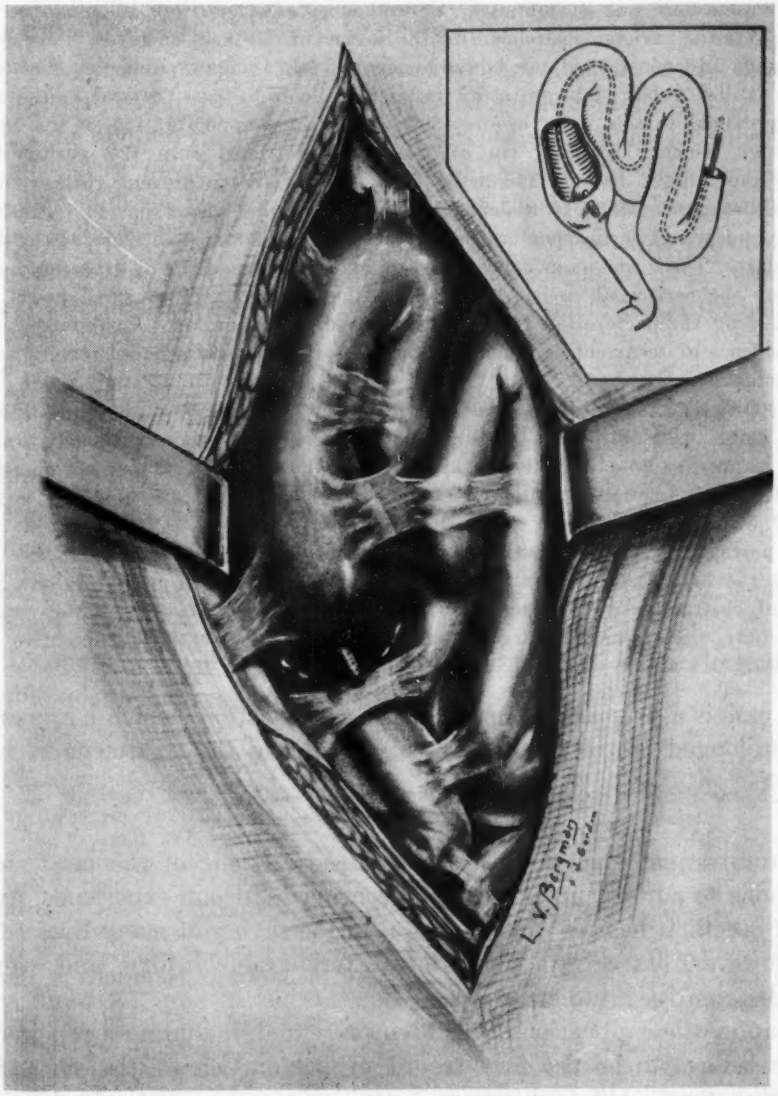

Fig. 4.—Illustrating the manner in which the balloon-inflated tube had perforated through the wall of the ileum proximal to the point of obstruction.

recurred, but as the tube progressed again, the symptoms and signs of obstruction subsided. During this period a moderate amount of flatus was expelled per rectum as a result of colonic irrigations.

On April 12, the distention and pain had diminished so considerably that the Miller-Abbott tube was clamped and fluids were permitted by mouth. One hour later the patient vomited, and therefore the suction drainage was quickly resumed. During the next few days the amount of drainage via the Wangensteen apparatus diminished rapidly. For one day prior to operation there was no drainage at all. It should be stated that during this period, when the patient's condition was gradually becoming worse, operation was advised and even strongly urged for a period of one week. However, because the senior author, who had previously performed the colectomy, was away on vacation, the patient did not consent to operation until his return on April 17, 1946.

On April 18, 1946, twelve days after the Miller-Abbott tube had been introduced, an exploratory laparotomy was performed. On opening the peritoneal cavity a moderate amount of serous fluid was encountered. Several loops of ileum were adherent to each other and to the anterior parietal peritoneum in the region of the first operative scar; one of the adhesive bands had constricted the bowel lumen to such a narrow diameter that it did not permit the Miller-Abbott tube with its inflated balloon to pass beyond this point. Immediately proximal to this point of obstruction there was a perforation in the wall of the ileum through which the metal tip of the tube protruded into the peritoneal cavity. Apparently the inflated balloon had acted as a check valve to prevent further progression of the tube through the wall of the ileum into the peritoneal cavity (Fig. 4). The bowel wall immediately adjacent to the perforation was acutely inflamed and covered by a fibrinoplastic exudate. There was no evidence of strangulation of bowel, or of gross leakage of ileal contents into the peritoneal cavity, inasmuch as the various loops of small bowel had completely walled off the perforation from the general peritoneal cavity. Furthermore, there was no gross evidence of recurrent carcinoma at the site of the previous bowel resection, or in the form of metastases elsewhere.

The metal tip of the tube was withdrawn into the lumen and the perforation in the bowel wall closed with two layers of silk sutures. Lysis of the adhesive bands was effected in such a manner as to eliminate the kinks in the bowel loops. Complete intestinal continuity without obstruction was thus restored. The Miller-Abbott tube was left in situ. The wound was closed in layers, using steel alloy wire sutures.

The postoperative course was completely uneventful. The Miller-Abbott tube was removed on the first postoperative day and the patient was given fluids orally. Signs and symptoms of obstruction did not recur. The patient had a spontaneous bowel movement on the fourth day. She was discharged symptom-free on the tenth postoperative day, and at the time of this report was enjoying good health.

This case is a dramatic example of the complications which may occur from the overprolonged use of the Miller-Abbott tube in the treatment of intestinal obstruction.

COMMENT

Gastrointestinal intubation may be considered one of the most significant contributions to surgery in the present century. In our experience, as well as in that of others, it has been instrumental in the saving of many lives. The procedure, however, has certain limitations. Irreparable injury, and even death, may result from its injudicious use.

Examples of complications have been presented, including a report of a case which we believe to be the first record of perforation of the small intestine during intubation. Although errors in its use are comparatively few, yet they are of sufficient seriousness to cause us to give thought to its potentialities for

harm. Uriburu,[18, 19] in two admirable articles, has reviewed the difficulties in the technique of passing the tube, and has suggested various methods of correcting these defects in order to obtain the best therapeutic result in each case. Harris[20] has further contributed to the progress of intestinal intubation by describing the clinical use of a single lumen, mercury weighted tube which has certain excellent technical advantages over the time-honored Miller-Abbott tube.

Aside from the difficulties in the technique and proper maintenance of suction, we should like to stress the importance of early recognition of the signs and symptoms of complications which arise from the very presence of the tube itself in the gastrointestinal tract. Prolonged intubation should be accompanied by frequent x-rays or fluoroscopy to check the position of the tube. The surgeon should not be lulled into a false sense of security by the apparent improvement in the patient's general condition. Intubation with the Miller-Abbott tube, to be effective, must show rapid and progressive improvement in the signs of intestinal obstruction. Improvement, to be considered significant, must continue even after the suction drainage has been discontinued and the tube has been clamped off. Any deviation from this simple premise invites the danger of fatality. Although the measure of usefulness of the Miller-Abbott tube far outweighs the total number of collected cases which illustrate its harmful effects, it is to be hoped that eventually the latter will be completely eliminated. Careful clinical attention to details of procedure will promote this fulfillment.

SUMMARY

1. A brief résumé of intestinal intubation has been presented, together with a discussion of the indications and contraindications for the use of the Miller-Abbott tube.

2. Complications resulting from the use of the Miller-Abbott tube have been mentioned and illustrated by examples from the current literature.

3. A case is presented which illustrates one further type of complication which has not been previously reported.

4. The dangers involved in the indiscriminate or overprolonged use of this valuable adjunct to abdominal surgery have been stressed.

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THE SURGICAL MANAGEMENT OF GASTROJEJUNOCOLIC FISTULAS

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INTRODUCTION

BRAUN, in 1899, reported the first gastrojejunal ("marginal") ulcer and in 1903 Czerny reported the first gastrojejunocolic fistula. Each of these conditions occurred as a complication following posterior gastrojejunostomy performed for duodenal ulcer. Since 1903 an increasing number of cases of gastrojejunocolic fistulas have been reported and number at the present approximately three hundred. This figure includes only those cases occurring as a complication following operation for gastric or duodenal ulcer.

The seriousness of a gastrojejunocolic fistula was soon demonstrated by the prohibitive mortality which occurred following attempts at correction (Table V). This high mortality rate served as a stimulus which resulted in the development of many and varied methods of surgical management, all aimed at a lowering of the operative death rate.

Unfortunately the number of patients with gastrojejunocolic fistula treated by any one method is too small to be of statistical value. Therefore, in evaluating any particular method of surgical management, the important consideration is the logic which forms the basis for treatment. With this in mind we reviewed the development of the surgical treatment of gastrojejunocolic fistula, and considered the multi-stage method with the use of a preliminary colostomy as described by Pfeiffer the most logical from the surgical standpoint.

In the five-year period from 1939 to 1944 we treated surgically six patients with gastrojejunocolic fistula. A preliminary colostomy was employed with satisfactory results in a consecutive series of five of the six cases. Although this series is small it is the largest single series reported with this type of treatment. These five cases plus a case of Mathewson's,[17] when added to the collective series reported by Pfeiffer[19] (1941), total twenty-one. All of these patients were treated by preliminary colostomy with one death (4.8 per cent). There is no doubt that more have been treated in this manner, but they were isolated cases and not reported.

It is our opinion that the value of performing a preliminary colostomy in the treatment of gastrojejunocolic fistula has not been generally recognized or sufficiently stressed. Since it is not the lot of any one person to treat many patients with gastrojejunocolic fistula, we wish to report our experience in the surgical management of six cases, stressing in particular the merits of performing a preliminary colostomy.

Information which may be of future statistical value is presented in Tables I to V.

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CLINICAL DISCUSSION

The six patients treated were all men. The average age was 43.5 years; the youngest was 29 and the oldest 53. The fistula in each case occurred as a complication of a posterior gastrojejunostomy done for duodenal ulcer. There was a history of a "marginal" ulcer in two cases and a questionable history in one case. The outstanding symptoms (Table I) were diarrhea and weight loss. These symptoms were present in all patients. In one patient, between thirty and forty bowel movements occurred during a twelve-hour daytime period. The greatest weight loss was sixty pounds and the average weight loss was forty pounds. Abdominal pain and a sense of weakness were the symptoms next in frequency. A slight to moderate amount of anemia was present in four cases. Undigested food particles were noted in the stools in three cases. Stercoraceous vomiting and eructations with a fecal odor were present in three cases. A clinical deficiency state was present in three cases. Impairment of appetite was noted in only one patient.

TABLE I. SYMPTOMS IN ORDER OF FREQUENCY OF OCCURRENCE

1.	(a) Diarrhea
	(b) Weight loss
2.	(a) Abdominal pain
	(b) Weakness
	(c) Anemia
3.	(a) Stercoraceous vomiting
	(b) Eructations with a fecal odor
	(c) Undigested food particles in stools
4.	Malnutrition
5.	Impairment of appetite

The shortest history of ulcer pain prior to operation (posterior gastrojejunostomy) was three years and the longest fifteen years, with an average of seven years. Relief of ulcer symptoms following operation occurred in all cases and varied from six months to nineteen years with an average period relief of 6.6 years (Table II). Following a barium enema, roentgenographic demonstration of the fistula was obtained in each case. However, following a barium meal the fistula was visualized in only three of the six cases.

The average duration of symptoms referable to a gastrojejunocolic fistula was fourteen months. The shortest period was five weeks and the longest six

TABLE II. SUMMARY OF SIX CASES IN WHICH POSTERIOR GASTROJEJUNOSTOMIES WERE DONE

CASE NUMBERS	AGE	SEX	DURATION OF ULCER SYMPTOMS PRIOR TO OPERATION (YR.)	RELIEF OF SYMPTOMS FOLLOWING GASTROJEJUNOSTOMY	DEVELOPMENT OF A MARGINAL ULCER FOLLOWING GASTROJEJUNOSTOMY	DEVELOPMENT OF A GASTROJEJUNOCOLIC FISTULA FOLLOWING GASTROJEJUNOSTOMY
1	46	Male	9	16 mo.	16 mo.	16½ mo.
2	53	Male	15	4 yr.	Negative history	4 yr.
3	37	Male	3	10 mo.	10 mo.	22 mo.
4	35	Male	3	6 mo.	6 mo.	7 yr.
5	52	Male	5	19 yr.	Negative history	19 yr.
6	45	Male	6	14 yr.	Negative history	14 yr.

years (Table II). In the latter case, fecal vomiting had been present for two years and diarrhea for six years. There was an associated severe nutritional deficiency. The patient was a chronic and complete invalid as the result of the illness.

A preliminary ascending loop colostomy was done in five of the six cases. Following colostomy a rapid improvement in the clinical condition of each patient occurred. There were pronounced beneficial effects in reference to the diarrhea, vomiting, and weight status. In three of the patients there was an immediate and complete cessation of the diarrhea following colostomy. In the remaining two a moderate to marked improvement in the diarrhea occurred. However, in one of the latter, loose stools per rectum persisted and contained undigested food particles. This would indicate a direct passage of food from the stomach through the fistula into the colon. Stercoraceous vomiting and foul eructations which were present in three cases ceased immediately. A gain in weight occurred in each patient varying from a low of eight pounds to a high of twenty-five pounds.

From our own clinical observations we are in agreement with Pfeiffer[19] (1941) in reference to the etiology of the diarrhea in cases of gastrojejunocolic fistula. This author believed that the diarrhea was secondary to the regurgitation of irritating colon contents into the stomach and jejunum. This produced a hyperperistalsis in the jejunum and a rapid passage of the small intestinal contents into the colon. In support of this concept is the clinical observation of immediate cessation or marked improvement in the diarrhea that occurs following a colostomy proximal to the fistula. Additional support has been obtained by fluoroscopic study and roentgenograms in three ways, namely, (1) the rapid passage of barium through the small intestines into the colon, (2) the comparative infrequent demonstration of the fistula by barium meal, and (3) the ease and frequency with which the fistula has been demonstrated by barium enema. Observations in the operating room and dissecting room have shown frequently the presence of a valvelike mechanism of the intestinal mucosa folds about the fistula which facilitated passage of colon contents into the stomach and jejunum, but not the reverse.

Prior to this concept it was the prevalent opinion that the cause of the diarrhea was the direct passage of stomach contents through the fistula into the distal colon. That this may still remain a factor in some cases is not denied. We previously cited our experience in one case in which diarrhea and the passage of undigested food particles persisted subsequent to a proximal colostomy. However, this may be considered an infrequent occurrence.

From the foregoing it may be stated that in a patient who develops an intractable diarrhea and has a previous history of having a gastrojejunostomy performed for ulcer, a gastrojejunocolic fistula should be considered as a possible causative factor.

TREATMENT

In the treatment of the first reported case of a gastrojejunocolic fistula (Czerny, 1903), a resection en bloc of the stomach, jejunum, and colon was done and a gastroenterostomy successfully re-established. Subsequent to this

and until a comparatively recent date this one-stage operation remained the treatment of choice. This operation usually consisted of a disconnection of the fistula and a simple restoration of normal gastrointestinal continuity.

In an attempt to improve the results of surgical management, modifications of the one-stage operation were introduced. Mason and Baker[16] (1931) advocated a complementary exteriorization of the transverse colon at the time of resection of the fistula in an attempt to reduce the hazard of leakage at the suture line and peritonitis. Three patients were reported treated in this manner with one death. Lahey and Swinton[13] (Fig. 1) treated two patients by an exclusion operation. The stomach was divided proximal to the fistula and an end-to-side gastrojejunostomy performed, by-passing the fistula.

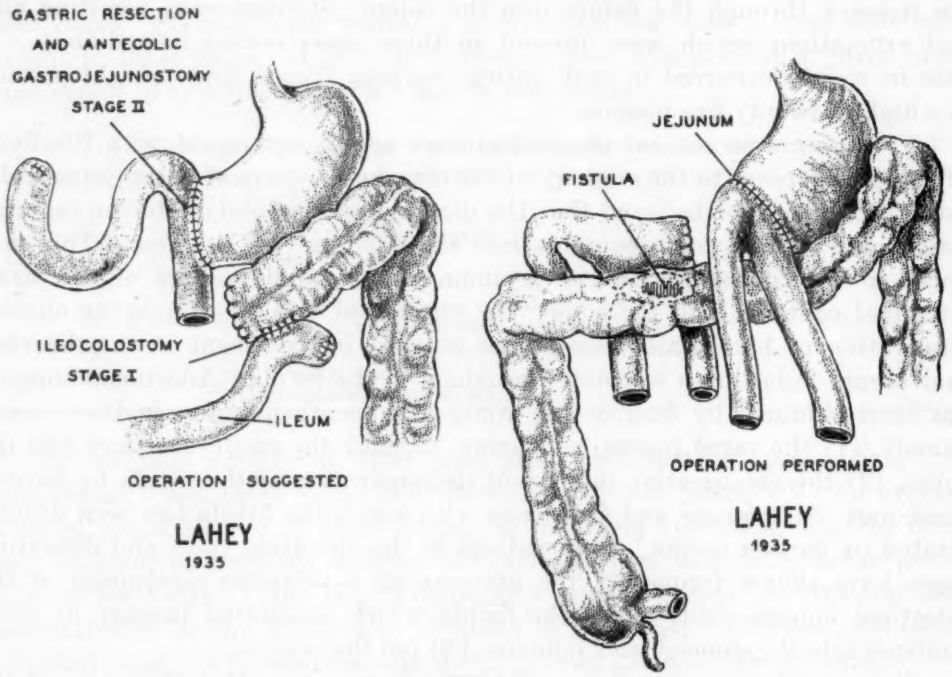


Fig. 1.

Allen[1] favored the use of an en bloc resection of the fistula and an aseptic anastomosis to avoid the lethal complication of peritonitis. Coller[6] advocated a period of adequate preoperative preparation of the patient and reported a reduction in the mortality rate from 40 to 12 per cent under this regime. In support of this, Gray and Sharpe,[12] following a period of intensive preoperative preparation, reported a reduction in the mortality rate from 61.5 to 27.7 per cent.

However, in general there was increasing dissatisfaction with the one-stage operation because of the associated high incidence of postoperative peritonitis. It has been stated (Findlay) that peritonitis has accounted for 60 per cent of the deaths following operations for gastrojejunocolic fistula.

To avoid the serious complication of peritonitis, various multi-stage operations were developed. Findlay[9] (Fig. 2) suggested the exteriorization of the

transverse colon (von Mikulicz) with the attached jejunal segment that contained the fistula, simple closure of the gastric stoma, and an end-to-end anastomosis of the jejunum. Scrimger[22] (Fig. 3) advocated the use of a gastric cuff from that portion of the stomach wall to which the jejunum was attached.

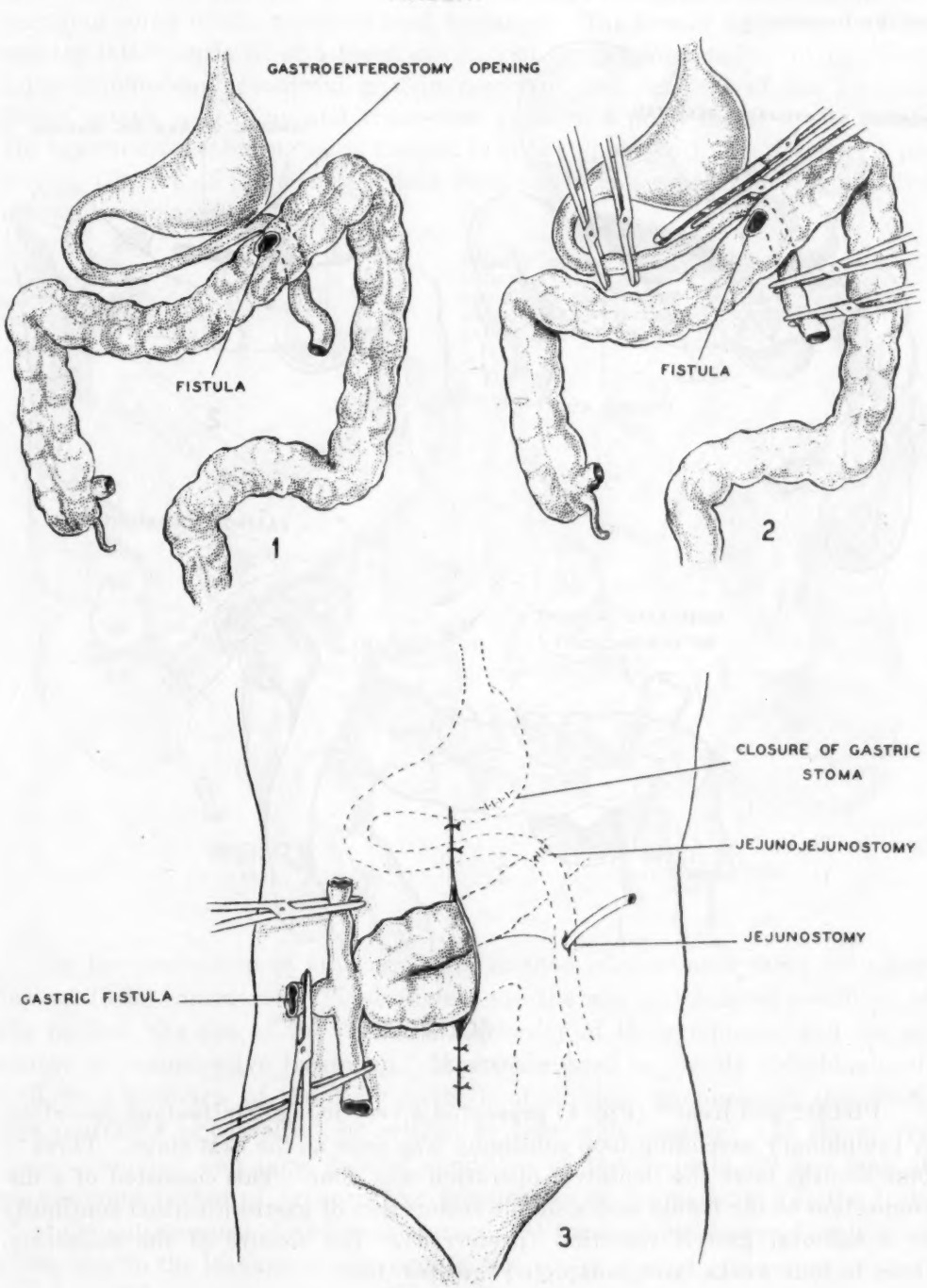
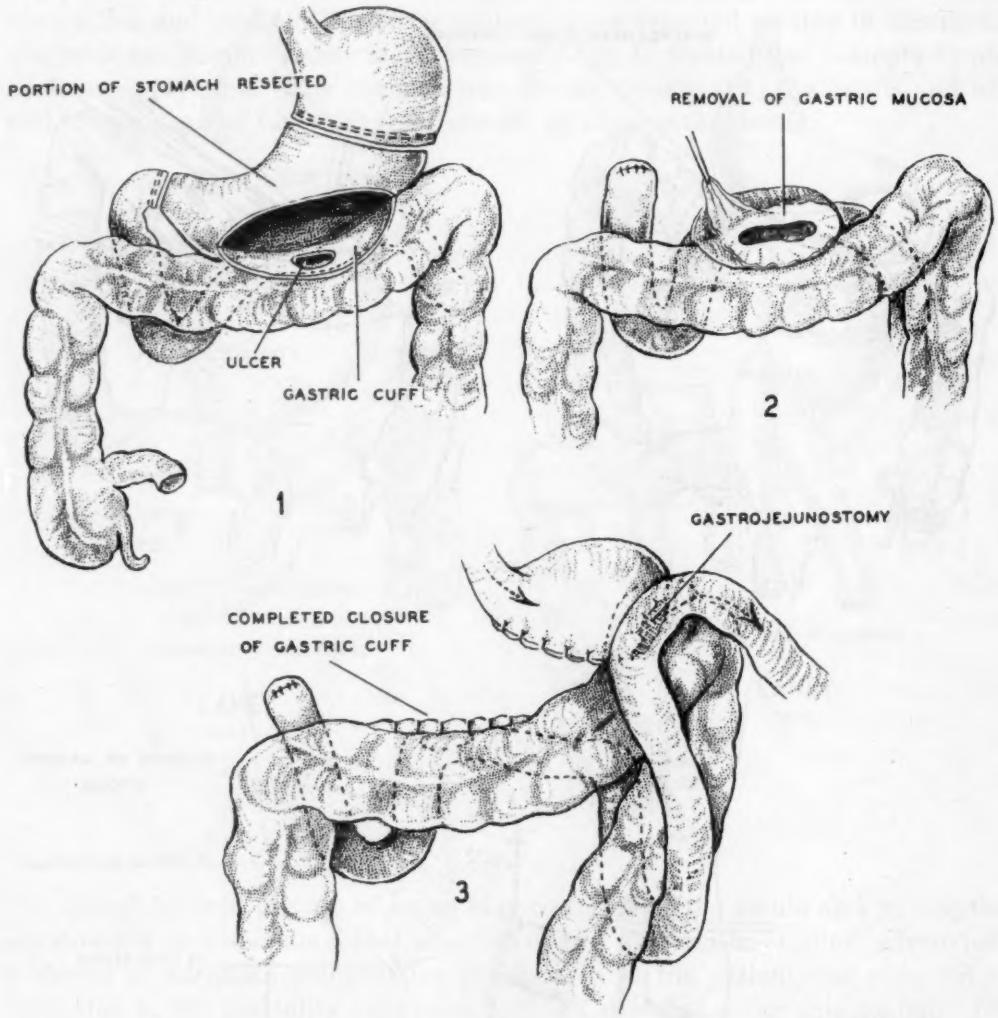


Fig. 2.

The mucosa of the gastric cuff was then removed and the two opposing surfaces sutured together, muscularis to muscularis. Subsequent to this a subtotal gastric resection was done. This operation was based on the principle that if a jejunal ulcer was shut away from the gastric contents it would heal; second, if exclusion of the jejunal ulcer could be accomplished without encroaching on the ulcer, a resection of the jejunum and transverse colon would not be necessary.



SCRIMGER

Fig. 3.

Pfeiffer and Kent[18] (Fig. 4) presented a very logical multi-stage operation. A preliminary ascending loop colostomy was done as the first stage. Three to four months later the definitive operation was done. This consisted of a disconnection of the fistula and a simple restoration of gastrointestinal continuity or a subtotal gastric resection (preferred). The closure of the colostomy, three to four weeks later, completed the operation.

Independent of Pfeiffer, Baker[11] (1940) advised a preliminary defunctioning ileostomy. One week subsequently the fistula was disconnected and a subtotal gastric resection was done.

Recently Marshall[15] (Fig. 5) presented a modification of the two-stage procedure suggested by Lahey and Swinton[13] (Fig. 1). In the first stage a side-to-side ileocolostomy was done between the terminal ileum and the descending colon with a terminal ileal exclusion. The second stage two to three months later consisted of a block excision of the jejunum and involved colon; jejunojejunostomy; subtotal gastric resection and removal of the terminal ileum, cecum, ascending and transverse colon to a point distal to the fistula. He reported fourteen patients treated in this manner with one death (7.1 per cent). Closure of the colonic fistula occurred in two cases following the first stage ileocolostomy.

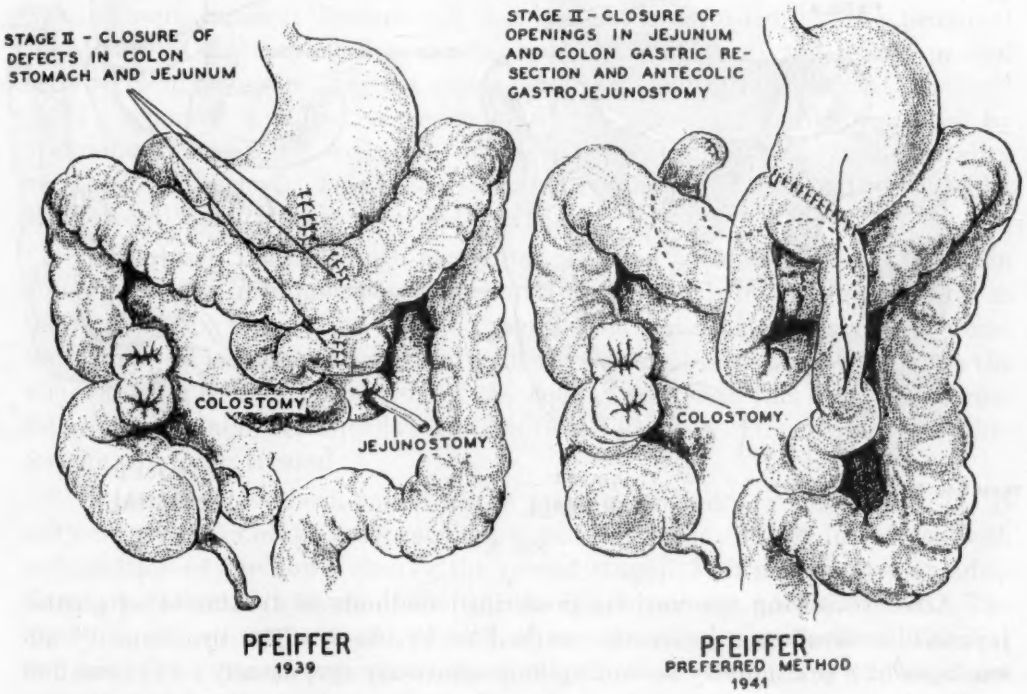


Fig. 4.

In the evaluation of any particular method of treatment there are many factors to be considered. These factors are the age and general condition of the patient, the size of the fistula, the severity of the symptoms, and the response to preoperative treatment. Each case must be rigidly individualized. Following a review of the early methods of surgical management, the excessive mortality appeared to be related to four main factors: (1) the severe malnourishment and poor general condition of the patient; (2) the lack of an adequate period of preoperative preparation of the patient; (3) the technical difficulties encountered at operation; (4) the high incidence of peritonitis secondary to the leakage of colon contents.

Control of one or more of these factors has been attempted in the development of improved methods of treatment. The importance of an adequate period of preoperative preparation has been mentioned.[6, 11] However, an unduly high mortality will continue to exist unless the complicating factor of peritonitis is controlled. The chief sources of peritoneal contamination are the extensive inflammatory reaction of the tissues about the fistula and the ever-present danger of leakage of colon contents at operation. It is, therefore, logical to assume that any method of surgical management which does not include the control of peritoneal contamination is not wholly adequate.

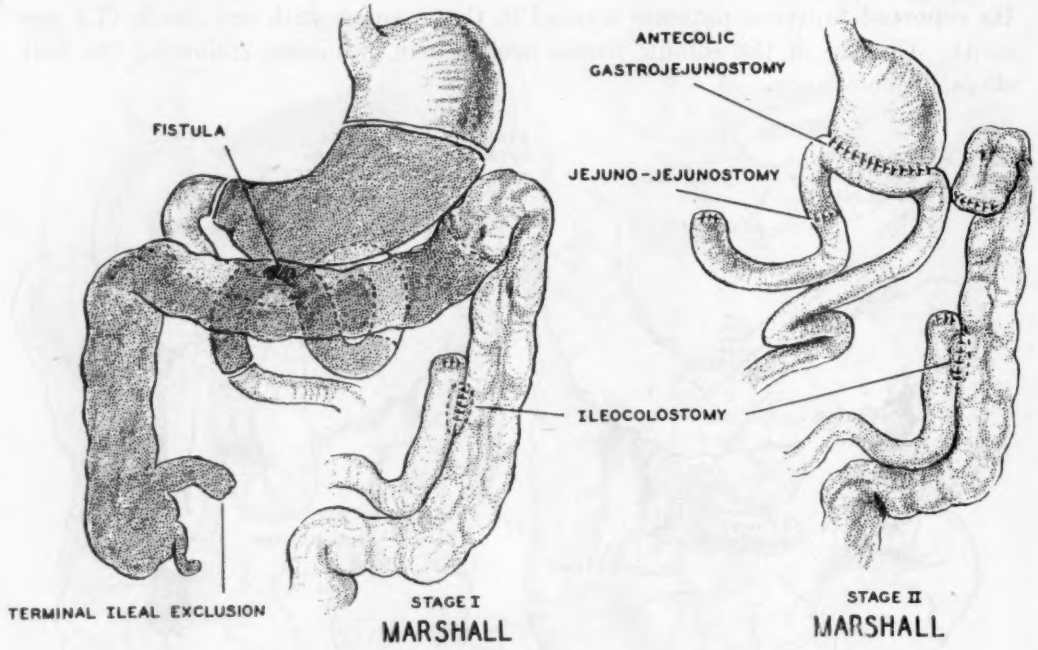


Fig. 5.

After reviewing the various prescribed methods of treatment of gastrojejunocolic fistula we prefer the method of Pfeiffer.[19] The proclaimed[18] advantages of a preliminary ascending loop colostomy are, namely: (1) cessation of diarrhea with a return of the patient to excellent physical status and hence reduction of the general risks of surgical intervention; (2) subsidence of the inflammatory reaction of adjacent tissues and the jejunal ulceration, thus reducing the risk of inflammatory complications in the surgical correction of the fistula; (3) freedom of contamination at operation and the later protection of suture lines in the repaired colon abolishing the danger of leakage. To these advantages may be added the technical simplicity of the operation. This is an important consideration because the patient is generally a poor surgical risk.

From a study of the alleged advantages of a preliminary colostomy we learn that it controls not one but all those factors which have been responsible for the prohibitive mortality in the treatment of gastrojejunocolic fistula.

Furthermore, the marked improvement in the general condition of the patient, the subsidence of the local inflammatory reaction about the fistula, and the lack of danger of peritoneal contamination with colon contents permit the surgeon to do a radical operation with a minimal risk. Moreover, this method is applicable to those patients who are in poor general condition and have large fistulas.

The use of this method has been justified following a study of the therapeutic results that have been obtained. Mathewson[17] (1941) reported three patients treated by preliminary colostomy with excellent results. A transverse colostomy was preferred to an ascending colostomy. In each case a subtotal gastric resection was done at the second stage operation. In one of the cases an intraperitoneal leakage at the site of repair of the fistulous opening in the colon was demonstrated by roentgenogram (barium enema). Recovery was without incident because of the protection afforded by the proximal colostomy. Colp[7] reported a spontaneous obliteration of the fistula proved both by roentgenogram (barium enema) and at subsequent operation. Pfeiffer[19] (1941) reported a collective series of fifteen cases, the patients treated by preliminary colostomy with one death (6.6 per cent), the lowest mortality heretofore published. This series included two of the three cases reported by Mathewson[17] and the case recorded by Colp.[7]

In contrast, the two-stage procedure reported by Marshall[15] has the main objection of performing an intraperitoneal anastomosis involving the colon as the first stage. Regardless of how "aseptically" an anastomosis may be done, the danger of leakage and peritonitis always exists. A second objection is the removal of such a large portion of the colon. Although this may not be considered formidable technically, we believe it to be too extensive an operation for the condition treated.

Objections have been raised to the use of a preliminary colostomy: (1) it subjects the patient to a subsequent wound infection; (2) it interferes with mobilization of the bowel during the second stage; (3) it necessitates an additional operation for closure of the fistula; (4) it prolongs hospitalization. The first two objections have not proved of any practical significance. The last two are minor considerations when compared to the seriousness of the illness for which the colostomy was done.

There has been a difference of surgical opinion as to the ideal definitive operation in the treatment of gastrojejunocolic fistula. Some prefer closure of the fistula and restoration of normal gastrointestinal continuity; others believe that gastric resection rather than simple restoration should be done.

The use of the first method is dependent upon the presence of a patent pylorus. This method has been used more frequently than any other, mainly because of the belief that it afforded the minimal surgical risk. Satisfactory results have been obtained in those cases in which the patient was in good general condition and the fistula small. However, the danger of a complicating peritonitis and the high incidence of recurrence of ulcer symptoms following operation are important objections to this method. Pfeiffer reported a

recurrence rate of 25 per cent; Lahey, 40 per cent. In our own experience with three patients treated in this manner, a recurrence of ulcer symptoms occurred in each one.

In reference to gastric resection, it is the opinion of many that it is too formidable an operation to do following the ablation of the fistula. They believe a resection should be done at a subsequent stage and then only if there has been a reactivation of the ulcer. This plan has been followed by Rife,[21] Ransom,[20] and Coller[6] in the majority of their cases.

We have surgically treated six patients with gastrojejunocolic fistula without a death. In the first patient, treated by a one-stage operation, the fistula was disconnected and normal gastrointestinal continuity restored. In the remaining five a preliminary colostomy was performed. In each of the latter a simple loop colostomy in the ascending colon, without spur formation, proved satisfactory. Colostomy drainage was established on the average of the fifth postoperative day by cautery colotomy. The second stage, the stage of definitive surgery, was done six to ten weeks later. The final stage, the closure of the colostomy, was performed on the average of four weeks after completion of the second stage.

In two of the five patients treated by preliminary colostomy, the fistula was disconnected and a simple restoration of gastrointestinal continuity was performed. In each of these a resection and end-to-end anastomosis of the jejunum was necessary.

In the remaining three, the fistula was disconnected, the openings in the jejunum and colon were closed by simple suture, and a subtotal gastric resection with an antecolic gastrojejunostomy was done. At the present we prefer this plan of treatment.

Our recent experiences with partial vagectomy in the treatment of duodenal ulcer have been very encouraging. When adequate accumulative data are obtained will this procedure prove to be the preferred method of surgical management? The application of partial vagectomy to the treatment of gastrojejunocolic fistula remains to be determined. The end results following simple closure of the fistula and restoration of normal gastrointestinal continuity have been unsatisfactory. The best results have been obtained with simple closure of the fistula combined with subtotal gastric resection. However, gastric resection subjects the patient to an increased surgical risk; symptoms are relieved at the sacrifice of two-thirds or more of the stomach; anemia and inability to regain weight are not infrequent postoperative problems.

The ideal would be the development of a more physiologic and less destructive method of surgical treatment. A suggested plan of treatment, following preliminary colostomy, would be the closure of the fistula combined with infradiaphragmatic partial vagectomy. A gastrojejunostomy also would be necessary if an associated obstruction of the pylorus was present. Whether or not partial vagectomy will approach the ideal in the treatment of gastrojejunocolic fistula, we do not know. However, we do believe it is a logical approach to the problem and worthy of extended clinical trial.

FOLLOW-UP STUDY

A complete follow-up was obtained in all cases. The shortest follow-up period was three years and four months, the longest eight years and six months.

In the follow-up study the cases were classified into two groups according to the type of definitive operation performed (Table III). Each group comprises three cases.

TABLE III. DEFINITIVE OPERATIONS PERFORMED*

GROUP	OPERATION	NUMBER OF CASES
I		3
	A. Disconnection of the fistulous communication and gastroenteric anastomosis; simple closure of the openings in the stomach and colon; resection of the jejunum and end-to-end anastomosis	2
	B. Disconnection of the fistulous communication and gastroenteric anastomosis; simple closure of the openings in the stomach, colon, and jejunum	1
II	Disconnection of the fistulous communication and gastroenteric anastomosis; simple closure of the openings in the colon and jejunum; subtotal gastric resection and antecolic gastrojejunostomy	3

*A preliminary colostomy was previously performed in all cases with the exception of B of Group I.

TABLE IV. POSTOPERATIVE COMPLICATIONS

COMPLICATIONS	NUMBER
Atelectasis	3
Prolapse of colostomy	2
Wound infection*	1
Evisceration of small intestine about colostomy	1
Hematuria†	1

*Secondary to closure of colostomy.
†Secondary to sulfadiazine therapy.

TABLE V. MORTALITY RATES FOLLOWING OPERATION FOR GASTROJEJUNOCOLIC FISTULAS

AUTHOR	YEAR	NUMBER OF CASES	NUMBER OF DEATHS	MORTALITY PER CENT
Lowey	1921	63	17	27.0
Verbrugge	1925	20	5	25.0
Lahey and Swinton	1935	8	5	63.0
Finsterer	1938	13	5	38.4
Walters and Clagett	1938	50	16	32.0
Gray and Sharpe	1941	49	18	36.7
Pfeiffer*	1941	15	1	6.6
Thomas†	1940	5	1	20.0
Mathewson‡	1941	3	0	0.0
Atwater, et al.	1943	41	11	27.0
Ransom§	1945	14	2	14.3
Marshall	1945	14	1	7.1
Barber and Madden‖	1946	6	0	0.0
Gossett (quoted by Finsterer)		28	12	42.8
Collective series treated by preliminary colostomy	1939-1946	21	1	4.8

*All cases had a preliminary colostomy.

†One case was secondary to a neoplasm of the splenic flexure; the remaining four were secondary to posterior gastrojejunostomy for ulcer. The death occurred in the latter group.

‡Two of the three cases are included in the collective series of Pfeiffer (1941). Each case had a preliminary colostomy.

§Ten consecutive cases without a death. Includes the series reported by Rife (1938); thirteen cases with two deaths (20 per cent).

‖In five of these cases a preliminary colostomy was performed.

In Group I are those cases in which the fistula was disconnected and a simple restoration of normal gastrointestinal continuity performed. Two of the three cases in this group had a preliminary ascending colostomy. In each of these cases a reactivation of the original duodenal ulcer occurred two weeks, three months, and four years, respectively, following discharge from the hospital. In each case, a subtotal gastric resection was done two years and five months, three months, and one year, respectively, subsequent to recurrence of ulcer symptoms. Following gastric resection the patients remained asymptomatic over a follow-up period ranging from three and one-half to four years. This improvement occurred despite the free use of tobacco and alcoholic beverages and a complete disregard of the prescribed diet.

In Group II are those cases in which a subtotal gastric resection was done. In each of the three cases of this group a preliminary ascending colostomy was performed. These cases were followed three years and nine months, three years and six months, and three years and five months, respectively, without recurrence of ulcer symptoms. Similarly, as in Group I, the follow-up study revealed that not one patient observed the proper diet or abstained from the use of alcohol and tobacco. Two of the patients admitted to the consumption of twenty to thirty glasses (10 ounce) of beer a day and the use of twenty to forty cigarettes daily.

A weight gain occurred in each case. The lowest gain was twenty and the highest sixty-one pounds with an average gain of thirty pounds. The highest weight gain (sixty-one pounds) occurred in a patient in Group II who had symptoms referable to a gastrojejunocolic fistula for six years prior to operation.

The important feature of the follow-up study shows that all the patients resumed a gainful occupation and performed without difficulty a full day's work. In three, the work was of a very arduous nature and the meal habits were irregular.

Our series of six cases is too small to permit one to draw conclusions. However, it may prove of interest to note that in each case in which gastric resection was performed as a definitive second stage procedure (Group II) the patients remained entirely free of symptoms. Similarly, those cases (Group I) in which reactivation of the original ulcer occurred, following a simple restoration of normal gastrointestinal continuity, remained asymptomatic following a subtotal gastric resection.

SUMMARY

Six cases of gastrojejunocolic fistula have been reported. In each case the fistula occurred as a complication of a posterior gastrojejunostomy performed for duodenal ulcer. The treatment was surgical in all cases. There were no deaths.

Intractable diarrhea and weight loss were the outstanding symptoms and were present in each case. The other symptoms in order of frequency were abdominal pain, weakness, anemia, foul-smelling eructations, stercoraceous vomiting, undigested food particles in the stools, malnutrition, and anorexia.

In all cases roentgenographic demonstration of the fistula was obtained following a barium enema. The fistulous communication was visualized in only three of the cases (50 per cent) after a barium meal.

The cases were classified according to the definitive surgical treatment into two groups, each group containing three cases. In Group I the fistula was disconnected and a simple restoration of gastrointestinal continunity performed. In Group II the fistula was disconnected and a subtotal gastric resection was done. A preliminary ascending loop colostomy was done in two of the cases of Group I and in each of the three cases of Group II.

A follow-up study was obtained in all cases. In Group I a reactivation of the original duodenal ulcer occurred two weeks, three months, and four years, respectively, following discharge from the hospital. In each, a gastric resection was subsequently performed with complete relief of symptoms over a follow-up period ranging from three to four years. In Group II there has been no recurrence of symptoms in a follow-up study varying from three and one-half to four years.

CONCLUSIONS

In the surgical management of gastrojejunocolic fistulas, the multi-stage operation described by Pfeiffer is preferred.

The first stage preliminary ascending colostomy produces a rapid and marked improvement in the general condition of the patient as manifested by immediate control of vomiting and diarrhea, improvement in appetite, gain in weight, and correction of malnutrition and anemia; it permits the subsidence of the massive inflammatory reaction about the fistula, thus facilitating the technical aspects of the second stage; it obviates the danger of peritoneal soiling with colon contents when the fistula is repaired.

In the second stage a disconnection of the fistula followed by a subtotal gastric resection is preferred to simple restoration of gastrointestinal continuity. Simple closure of the fistula combined with infradiaphragmatic partial vagectomy may prove of value on extended clinical trial.

Acknowledgment is made to Dr. A. Iason for information completing the follow-up study in Case I.

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SURGICAL DRAINS MADE OF VINYL PLASTIC FILM

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THERE are certain disadvantages to the time-honored use of gutta percha as surgical drains. There is a slight tendency for the tissues to become adherent to it and hence removal may be a painful process. Gutta percha, like all types of rubber, tends to deteriorate with age and thereby loses tensile strength. It is this loss of tensile strength which poses the real danger of leaving fragments of the drain in a wound because they may break off during removal.

One of the vinyl plastics is commercially available as a thin, soft, pliable, colorless semitransparent film of great tensile strength. It has been used for drains in over 100 abdominal operations in our institution during the past year with eminently satisfactory results.

This material may be boiled or autoclaved without altering its properties. Extreme heat (far above sterilization temperature) causes the film to soften and become tacky. However, the physical properties return to normal on cooling. The vinyl plastic is not affected by soap, water, alcohol, or most solvents. It is chemically inert and is not appreciably affected by age, retaining its tensile strength, tenuity, and semitransparency. The chemical inertness also renders this material nonirritating to tissues.

The vinyl plastic film is prepared for surgical use by scrubbing with soap and water, cutting into pieces of convenient size, placing a thin section of gauze between each sheet to prevent adherence, sterilization in the autoclave, and storage in 70 per cent alcohol.

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Recent Advances in Surgery

CONDUCTED BY ALFRED BLALOCK, M.D.

I. THE INTERNAL STATE OF THE SEVERELY WOUNDED MAN ON ENTRY TO THE MOST FORWARD HOSPITAL

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THE effects on the human body of the destructive forces of warfare have been stated many times in terms of organic damage and tissue loss. Our concern is rather with the internal state of the wounded man. The gross tissue damage is obvious, or becomes so on surgical exploration; therefore, our purpose is to describe the latent consequences of the wound, revealed in impairment of organic function and in abnormalities of the blood volume and chemistry, and in the urine. These initial studies were made shortly after the patient entered the most forward hospital. They were made before either vigorous resuscitative measures or operation had yet been undertaken.

BACKGROUND MATERIAL

Account must be taken of the nature and type of the wound, and of space and time as well, for delay along the evacuation trail and the response of the patient to his wound and subsequent management all influence the factors under study and, bracketed with the laboratory data, give significance to them. Of the 186 seriously wounded patients studied during the course of this work, 108 were examined (including blood chemistry studies) rather completely on entry to the hospital.

Evacuation Time From Wounding to Surgery

Since delay along the evacuation route may greatly influence the condition of the patient found on arrival at the most forward hospital, some indication of the order of this will be given. The first 100 cases listed in Table I were chosen at random from those observed in this study, during the relatively quiet part of the fall, winter, and spring period. The other two batches of data are based upon casualties produced during drives. In the last period, those concerned thought that, considering the circumstances, the evacuation to the hospital progressed exceptionally rapidly. These 191 very seriously wounded patients were the men in the worst condition drawn from about 7,500 battle casualties

The material presented here has been drawn from "The Physiological Effects of Wounds," based upon a report prepared by a Board for the Study of the Severely Wounded, Mediterranean Theater of Operations, United States Army: Tracy B. Mallory, Fiorindo A. Simeone, Henry K. Beecher, Eugene R. Sullivan, Charles H. Burnett, Seymour L. Shapiro, and Louis D. Smith. This and other material will eventually be published as a monograph by the Government Printing Office. Extracts from this monograph will appear under varying authorship.

(see the section in the Monograph mentioned in the footnote below, on frequency of complications for the method of estimating this) who reached a forward hospital alive.

Type and Location of Wounds

Of the 186 patients studied, 33 had peripheral wounds without fracture. These were nearly all on the extremities. Five of these were listed as having minor (less severe) wounds in this category with their major (more severe) wounds tabulated elsewhere.

There were 83 patients having peripheral wounds with fracture. Again, these were nearly all extremity wounds; 15 had traumatic amputation of an extremity. In 23 cases listed in this group, more important wounds are listed under other headings.

In 34 patients thoracic wounds were present; in 7 of these the thoracic wound was less important than the other wounds present.

TABLE I. TYPICAL DELAY ALONG THE EVACUATION STREAM

SOURCE AND PERIOD OF COLLECTION	NUMBER OF CASES	AVERAGE TIME FROM WOUNDING TO BATTALION AID STATION	AVERAGE TIME FROM BATTALION AID STATION TO COLLECTING COMPANY	AVERAGE TIME FROM COLLECTING COMPANY TO CLEARING STATION	AVERAGE TIME FROM CLEARING STATION TO FORWARD HOSPITAL	AVERAGE TIME FROM FORWARD HOSPITAL ENTRY TO OPERATION	AVERAGE TOTAL TIME FROM WOUNDING TO SURGERY
North of Florence, Italy; Sept., 1944, to March, 1945	100	2.68	2.95	1.98	1.41	5.38	14.40
Loiano, Italy; April, 1945	47	4.65	1.43	0.93	0.56	8.28	15.85
Via Reggio, Italy; March and April, 1945	44	4.59	0.84	0.99	0.60	5.13	12.15

Time is expressed in hours.

Of the group, 56 patients had intra-abdominal wounds. A total of 19 patients had thoracoabdominal wounds; one of these had separate wounds of the chest and abdomen. Liver wounds were present in 25, absent in 160, not known in 1 patient. Wounds of the kidney were present in 20, absent in 165, and uncertain in 1 patient. In 11 of the 20 patients with kidney damage, nephrectomy was done. In 10 patients wounds of the urinary tract (bladder or above) were present.

Crushing injuries were found in 9 patients; 3 had spinal cord injury.

Clinical Condition of the Patient on Arrival at the Most Forward Hospital

Pain.—The frequency and severity of pain were extensively studied shortly before the Board's work was undertaken and has been described elsewhere.[1] The types of patients observed there were similar to those considered by the Board. Part of the data obtained were as shown in Table II.

TABLE II. TWO HUNDRED FIFTEEN PATIENTS WITH MAJOR WOUNDS
Standard Errors of the Mean Are Shown

TYPE OF WOUND	COMPOUND FRACTURES OF LONG BONES	EXTENSIVE SOFT TISSUE WOUNDS	PENETRATING WOUNDS OF THORAX	PENETRATING WOUNDS OF ABDOMEN	PENETRATING WOUNDS OF CEREBRUM
Number of patients	50	50	50	50	15
Patient's age (yr.)	24.8 ± 0.9	24.5 ± 1.1	24.5 ± 0.8	22.7 ± 0.6	25.1 ± 1.4
Time since wounding (hr.)	12.5 ± 1.3	11.3 ± 1.4	9.8 ± 1.0	7.2 ± 0.7	7.9 ± 1.4
Average total dose of morphine (mg.)	1 pt.—none* 49 pts. avgd. 27.0 ± 1.5	11 pts.—none* 39 pts. avgd. 27.0 ± 2.7	11 pts.—none* 39 pts. avgd. 25.0 ± 1.8	5 pts.—none* 45 pts. avgd. 29.0 ± 2.2	8 pts.—none* 7 pts. avgd. 19.8 ± 4.2
Average latest dose of morphine (mg.) (spread as above)	22.6	19.5	21.2	25.0	19.8
Time since latest morphine (hr.)	7.0 ± 0.8	7.2 ± 0.6	6.5 ± 0.6	4.8 ± 0.7	6.2 ± 1.5
Degree of pain (number of patients in each group)	19 none 12 slight 7 moderate 12 bad	19 none 15 slight 8 moderate 8 bad	15 none 18 slight 11 moderate 6 bad	7 none 5 slight 14 moderate 24 bad	9 none 5 slight 0 moderate 1 bad
Further pain relief therapy wanted (no. of patients)	11 yes 39 no	9 yes 41 no	10 yes 40 no	27 yes 23 no	1 yes 14 no

*Not included in average.

The incidence of severe pain is surprisingly low. In the report referred to, data were presented to show that the patients who had severe pain were not to be accounted for as having had less morphine or having had it longer ago than patients who reported little or no pain.

It was also pointed out that three factors are chiefly important in the distress of the wounded: pain, mental distress, and thirst. In the severely wounded patient in good general condition the first two factors are important. In the man in shock, thirst is the main, and often only, cause of evident distress, but this may be severe.

Shock.—The view might be proposed in a given case that shock is either present or absent and that to try to differentiate between degrees of it is futile. Our empirical finding was, however, that it was instructive to separate the patients into four categories: no shock, slight shock, moderate shock, and severe shock.

The patients were arbitrarily divided into four groups according to the following signs, set down here because it will be useful to refer to them later in conjunction with the physiologic findings encountered.

These signs are inadequate, of course, for management of a case, because a comprehensive appraisal of the patient's condition must include not only an accurate concept of the present state of affairs, but a shrewd estimate of his probable course in the immediate future. This will be discussed in detail later. For the present, here are the arbitrary criteria for grouping the seriously wounded men (Table IIA).

On admission:

	3	patients, or 1.6%,	were unclassified
	34	patients, or 18.3%,	were in no shock
	37	patients, or 20.0%,	were in slight shock
	55	patients, or 29.5%,	were in moderate shock
	57	patients, or 30.6%,	were in severe shock
Total	186	100.0%	

This group includes patients who were not seen on admission by a member of the Board, but were classified on the basis of the available clinical data and on discussion with officers who had seen them. In the following group of 108 patients all were seen on admission by a member of the Board. Possibly the degree of shock was more uniformly classified here than in the other group; however, the percentages are about the same in the two series.

	1	patient, or 0.9%,	was unclassified
	20	patients, or 18.5%,	were in no shock
	27	patients, or 25.0%,	were in slight shock
	34	patients, or 31.5%,	were in moderate shock
	26	patients, or 24.1%,	were in severe shock
Total	108	100.0%	

Examination of the records of 167 wounded men (Table III) fails to show any correlation between time from wounding until examination (clinical ap-

TABLE IIA. GRADING OF SHOCK*

DEGREE OF SHOCK	BLOOD PRESSURE (APPROX.)	PULSE QUALITY	SKIN			THIRST	MENTAL STATE
			TEMPERATURE	COLOR	CIRCULATION (RESPONSE TO PRESSURE BLANCHING)		
None	Normal	Normal	Normal	Normal	Normal	Normal	Clear and distressed
Slight	To 20% decrease	Normal	Cool	Pale	Definite slowing	Normal	Clear and distressed
Moderate	Decreased 20 to 40%	Definite decrease in volume	Cool	Pale	Definite slowing	Definite	Clear and some apathy unless stimulated
Severe	Decreased 40% to non-recordable	Weak to imperceptible	Cold	Ashen to cyanotic (mottling)	Very sluggish	Severe	Apathetic to comatose, little distress except thirst

*It will be observed that sweating, nausea, and vomiting are not mentioned in this table, although these criteria were much referred to in World War I reports. In our experience they are not common and are of no use in estimating the extent of shock. They are probably more closely related to psychologic factors, or to the nature of the wound, or to morphine administration than they are to shock. The pulse rate can be influenced by too many unimportant factors to have value in estimating degree of shock; pulse quality, however, is important. It will also be observed that the last three columns of the table include items not ordinarily considered in evaluating a patient's condition. Since we found them useful, they are included.

praisal and blood analysis) and the severity of shock. The time elapsed in each of the four groups is the same. There is, however, a striking correlation of shock severity with blood loss, as shown elsewhere.

Table IV shows the wound composition of each of the shock groups (see also Table V). It merits some comment. If the patients with traumatic amputation of extremities are added to those having compound fractures of long bones, cases often very similar as far as blood loss goes, one can see (Chart 1) a sharp rise of incidence of these cases as one deals with groups of patients in increasingly poor condition.

In the section on blood loss it will be shown that the greatest loss of hemoglobin occurs in wounds that involve compound fractures of long bones or traumatic amputation. Since these wounds are most prevalent in the severe-shock group, one can generalize with probability of accuracy and say that it is the wounds that are associated with great hemorrhage that cause the severe shock. Reasons for laboring this rather obvious point will be discussed later.

In contrast to the rising incidence of the severe extremity wounds just referred to, the percentage of penetrated abdomens, although rather high, shows no consistent rise in the four groups. In the severe-shock group, abdominal wounds are definitely less often a cause of the poor condition than the other

TABLE III. RELATIONSHIP OF DEGREE OF SHOCK ON HOSPITAL ARRIVAL TO TIME FROM WOUNDING

DEGREE OF SHOCK	NONE	SLIGHT	MODERATELY SEVERE	SEVERE
Time from wounding to hospital entry (hours)	6.7 ± 0.9 (29 cases)	7.6 ± 0.8 (36 cases)	6.4 ± 0.5 (52 cases)	6.9 ± 0.7 (50 cases)

Standard errors of the mean are shown.

type of wounds. (Incidentally, one can see no evidence here that clostridial infection plays an important part in producing shock.)

The question might be raised as to whether the relative importance of abdominal wounds as a cause of shock, in comparison with the serious extremity wounds, has been exaggerated. The poor prognosis often encountered in patients with abdominal wounds probably has a great deal to do with the apprehension felt in the presence of such lesions. The concealed hemorrhage or concealed contamination often present here may lead to profound shock. Therefore, while on the average, abdominal wounds may be less often a cause of severe shock on hospital entry than the serious extremity wounds, the impossibility of an accurate preoperative appraisal of the abdominal wound makes it difficult to exaggerate its potentialities.

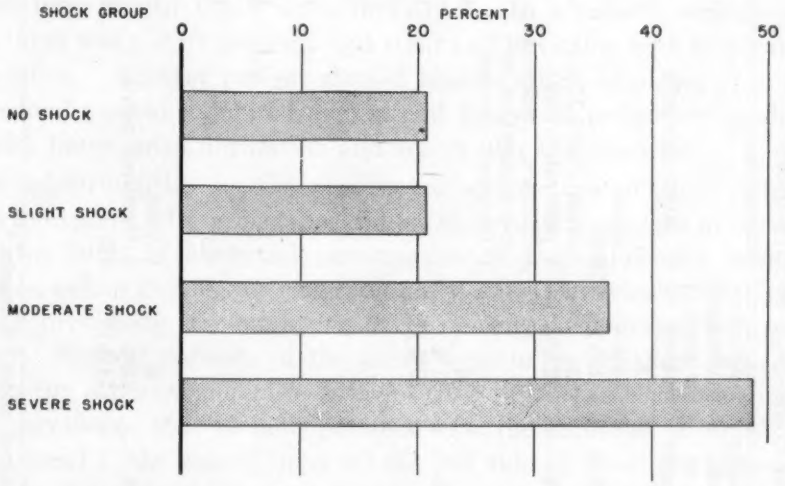


Chart 1.—Incidence of serious extremity wounds in the several shock groups; traumatic amputation or compound fracture of long bones.

Shock will be discussed in each of the following sections. For example, see particularly the section on Blood Loss. An attempt will be made in all cases to correlate degree of shock with the data under discussion. This, of course, will not always be possible.

The Cardiovascular System.—The material on the cardiovascular system is discussed at this point rather than before the immediately preceding section on shock, since we wish to arrange the findings, when possible, in terms of the several shock groups referred to there.

Electrocardiographic observations: Fifty-eight records were made of 30 patients in the severe-shock group, during shock and after recovery. This study was made before the Board was organized, by Burnett, Bland, and Beecher;[2] but since the observations were made upon the same type of patients as those studied by the Board and under similar circumstances, a brief note will be inserted here as to the results found.

In 10 of the patients, one-third of this group, the blood pressure could not be measured on entry. In the other two-thirds, the degree of circulatory collapse

TABLE IV. ONE HUNDRED TWENTY-ONE PATIENTS CLASSIFIED AS TO DEGREE OF SHOCK ON ADMISSION WITH CHIEF WOUND COMPOSITION OF EACH GROUP

DEGREE OF SHOCK	NUMBER CLASSIFIED	PENETRATED ABDOMEN	PENETRATED CHEST	LACERATED SOFT TISSUE	TRAUMATIC AMPUTATION OF EXTREMITY	COMPOUND FRACTURE OF LONG BONES	MISCELLANEOUS	REMARKS
None	24	7 29%	1 4%	5 21%	3 13%	1 4% (8%)*	7 crush 29%	1 abdominal case had also fracture, compound, comminuted, of humerus
Slight	24	7 29%	3 12.5%	5 21%	2 8%	3 12.5%	1 crush (*total* 17%) 1 penetrated face 1 fracture, compound, comminuted, sacrum 1 fractured vertebra	1 abdominal case had also a penetrating chest wound
Moderate	36	13 36%	8 22%	5 14%	6 17%	4 11% (19%)*		3 abdominal cases had also penetrating chest wounds 1 abdominal case had also fracture, compound, comminuted, of both bones of leg 1 abdominal case had also fracture, compound, comminuted, of humerus 1 chest case had also fracture, compound, comminuted, of arm bones 1 soft tissue case had also a fractured skull 1 traumatic amputation case had also fracture, compound, comminuted, bones of other leg
Severe	37	10 27%	5 14%	3 8%	9 24%	8 22% (24%)*	1 crush 1 fractured pelvis 5%	2 abdominal cases had also penetrating chest wounds 1 chest case had also fracture, compound, comminuted, of humerus 1 chest case had also fracture, compound, comminuted, of ilium

*Percentages marked include the compound fractures listed under "Remarks."

TABLE V

CONDITION OF THE PATIENT	INCIDENCE OF TRAUMATIC AMPUTATION OR COMPOUND FRACTURE OF LONG BONES (PER CENT)
No shock	20.8
Slight shock	20.8
Moderate shock	36.1
Severe shock	48.6

was somewhat less severe, but even so the systolic blood pressures were 60 to 70 mm. Hg and the diastolic, 20 to 40. Definite abnormalities of the electrocardiograms were observed in 5 of the 30 patients. The most striking feature was the normal character of the remaining 25 patients.

Of the 5 patients with abnormal electrocardiograms, 2 showed striking but transient inversion of the T wave in Lead I. In a patient with intrathoracic injury, there was a shift from marked right axis deviation back to normal following operation. Another patient showed bizarre QRS complexes of low voltage, and the final patient exhibited an unusual degree of temporary cardiac irritability with paroxysmal fibrillation and ventricular tachycardia.

The abnormalities in the electrocardiograms are of some interest, and difficult to explain. In no instance did we observe clinical signs of cardiac weakness in the form of abnormal accentuation of the pulmonary second sound, basal râles, gallop rhythm, or congestion of the cervical veins or of the liver. As remarked previously, the majority of the electrocardiograms were normal in character. Several patients in the series were in severe shock with low blood pressures for a period of hours with no effect upon the electrocardiogram. It may be significant that in both patients with the transient inversion of the T waves in Lead I, the wound involved the left side of the chest, although as far as could be determined by x-ray examination and at the time of operation, the heart and pericardium escaped injury. Furthermore, the transient nature of the inversion was more in accord with a temporary functional disturbance (possibly hypoxia) than with lasting tissue injury.

The pulse rate: There was no significant difference in rate between the four groups (Table VA). The pulse rates were taken as near as possible to the time the condition of the patient was evaluated. When it was imperceptible, the next recorded pulse rate was taken unless the record showed evidence that the case was resuscitated or nearly so.

The finding that the average, as well as minimum and maximum, pulse rates were the same in all degrees of shock was surprising. This is explained in two ways: (1) the tachycardia in the lesser degrees of shock may have been due in

TABLE VA. THE PULSE RATE IN DIFFERENT DEGREES OF SHOCK

DEGREE OF SHOCK	NONE (13 CASES)	SLIGHT (24 CASES)	MODERATELY SEVERE (34 CASES)	SEVERE (35 CASES)
Minimum pulse rate	70	88	80	60
Maximum pulse rate	140	150	160	144
Average	103 ± 7.2	111 ± 3.4	113 ± 3.6	116 ± 3.3

part to excitement and (2) in some cases the elevation in the pulse rate (and the vasoconstriction accompanying it) may have been adequate to ward off the signs of shock. It is interesting that even patients judged to be in severe shock can have a pulse rate as low as 60 per minute. In such a case other factors clearly outweighed this one in grading the shock. Of greater significance than the actual rate of pulse is its volume, which often is decreased so far in severe shock that the pulse can no longer be felt.

The blood pressure: The blood pressures were analyzed only for those cases where they were recorded at the time the condition of the patient was evaluated. There were 70 such cases, and the circulating blood volume was determined in all of them.

A significant fall in the systolic blood pressure did not occur until the group considered to be in moderately severe shock was reached (Table VB). These patients had lost 33.6 ± 3.2 per cent of their calculated normal blood volumes and nearly 50 per cent of the total circulating hemoglobin. With more severe degrees of shock, the systolic blood pressure fell more rapidly. The (average) systolic blood pressure in severe shock was 49 ± 7.6 mm. Hg. This group had lost approximately one-half the calculated normal blood volume.

Table VB shows a progressive drop in the diastolic blood pressure with increasing degrees of shock. The average diastolic blood pressure of patients in severe shock is one-half that of patients in moderate shock.

As the severity of shock increases, there is a significant and progressive decline in the pulse pressures (Table VB). This fits the clinical observation that the volume of the pulse is closely correlated with the degree of shock.

TABLE VB. THE BLOOD PRESSURE IN RELATION TO DEGREE OF SHOCK

DEGREE OF SHOCK	SYSTOLIC BLOOD PRESSURE			DIASTOLIC BLOOD PRESSURE			PULSE PRESSURE		
	LOWEST	HIGHEST	AVERAGE	LOWEST	HIGHEST	AVERAGE	LOWEST	HIGHEST	AVERAGE
None (13 cases)	108	150	126 ± 11.9	64	80	75 ± 1.5	30	80	52 ± 4.1
Slight (20 cases)	90	140	109 ± 3.0	40	86	66 ± 2.7	28	80	44 ± 2.7
Moderate (21 cases)	30	136	95 ± 4.9	20	90	58 ± 3.5	10	56	36 ± 2.8
Severe* (16 cases)	0	80	49 ± 7.6	0	68	25 ± 5.8	0	58	24 ± 4.7

*Where the values were unmeasurable (2 cases) they were considered to be 0.

"Irreversible" changes in the cardiovascular system: Everyone dealing with patients in shock has the problem of the patient who fails to respond to the transfusion of blood thought adequate under ordinary circumstances. The failure of response is often attributed to the supposition that "irreversible" changes have taken place during prolonged hypotension, ischemia, and anoxia. This is discussed also in the section on Blood Loss. In most instances, adequate explanation is found for the failure of patients in shock to respond to transfusion; some common examples are concealed and continuing hemorrhage, hemothorax, irritant contamination of the peritoneum, peritonitis, clostridial myositis, and fat emboli. Four typical cases are presented.

CASE 1 (No. 77).—The patient had a severe thoracoabdominal wound. He was received at a forward hospital in severe shock eight hours and fifteen minutes after wounding. Resuscitation was continued for nearly nine hours. During that time he received only 1,500 c.c. of blood. His condition failed to improve and he was operated upon, but did not survive the operation. Autopsy showed massive collapse of the right lung with a plug of mucus in the right main bronchus. The lower lobe of the left lung was collapsed and about one-third of the left upper lobe was atelectatic. There was gross dilatation of the right ventricle of the heart. Histologically, minimal evidence of fat embolism in the pulmonary vessels was found, but thought to be of no clinical significance.

Comment: There was adequate cause for the failure of this patient to respond to resuscitation. More aggressive measures should have been taken, including bronchoscopy and the use of more blood in less time. There should have been more concern when little improvement was seen during the first three hours after admission to the hospital.

CASE 2 (No. 45).—The patient had a severe abdominal wound and was admitted in severe shock to a forward hospital eight hours after wounding. During the next three hours, two units (600 c.c.) total volume of plasma and one liter of blood were transfused. The blood pressure during that time changed from imperceptible to 90 systolic and 70 diastolic. He was given 300 c.c. more of plasma and 500 c.c. of 2 per cent sodium bicarbonate solution intravenously. This was the optimum time for surgery. Operation was delayed, however, and five hours later, the blood pressure was again unmeasurable. It was restored to 86 systolic and 60 diastolic after one liter of blood, and operation was performed, which lasted four hours. At operation the abdominal cavity was found "full of blood." The blood pressure and pulse were unmeasurable during much of the operation. The patient did not regain consciousness and died three and three-quarters hours after the end of the operation. Autopsy showed a perforation of the inferior vena cava. There was evidence of minimal fat embolism in the pulmonary vessels histologically, probably of no clinical significance.

Comment: The recurrent hypotension in this patient was probably due to continued extraperitoneal and intraperitoneal hemorrhage. Operation should have been performed when he showed good response to resuscitation during the first three hours after admission to the hospital.

CASE 3 (No. 100).—The patient had multiple wounds involving both arms, the left thigh, and the face. There were compound fractures of the left humerus, radius, and ulna, and of the right ulna. He also had a transection of the right femoral artery with vascular insufficiency in the leg. He was admitted in severe shock to a forward hospital three and one-half hours after wounding. Within ninety minutes the patient received 300 c.c. of plasma and two liters of blood. He showed improvement but the blood pressure was still only 80 systolic and 50 diastolic. The pulse was 144. Three hours after admission the blood pressure was 90/58. Operation was delayed for three more hours. During operation the recorded blood pressure never fell below 85 mm. Hg systolic. Before, during, and after operation, he received 4,500 c.c. blood, and ten hours after operation he had hypotension and looked pale and "anemic." A transfusion was started. One hour later the patient suddenly died. Ten minutes earlier he had carried on an intelligent conversation. Pulmonary embolus was suspected, but at autopsy no cause could be found for the sudden death. Microscopically, a moderately severe grade of fat embolism was found in the lungs. It may well have contributed to the unexpected death of the patient.

Comment: The question was asked if the five- or six-hour period of hypotension in this patient could have caused irreversible changes in the cardio-

vascular system so that it simply "gave out" when it did. The question cannot be answered with certainty. The fat embolism, in retrospect, appears to be the more important consideration.

CASE 4 (No. 120).—The patient had a simple penetrating wound of the thigh caused by a shell fragment. The femoral artery below the origin of the profunda femoris was severed. During evacuation he received four units of plasma and when he reached the evacuation hospital, about nine hours after wounding, he must have appeared in good condition for no resuscitation was thought necessary, and operation was performed four and one-half hours after admission. The femoral artery, vein, and nerve were found completely transected. The vessels were ligated and the foreign body was removed. At the close of the operation, the blood pressure was only 70 mm. Hg and remained between 70 and 60 throughout the day. In spite of this, the patient seemed to have good color and the skin was not cold. One liter of blood did not improve the blood pressure. The right leg looked as though it would not survive. The patient developed anuria and died forty-eight hours after operation. Autopsy showed nothing to account for the hypotension postoperatively. There was no concealed hemorrhage and no evidence of clostridial myositis in the involved extremity. There was no evidence of fat embolism histologically.

Comment: This patient, no doubt, had lost more blood than was realized at the time he was admitted to the hospital.

Resuscitation

The principles on which resuscitation was carried out, as well as the routine procedures involved in caring for the typical patient, have been described in a section of the Appendix of the Monograph mentioned in the footnote, page 672.

In the 108 patients who were fairly completely studied shortly after their hospital entry, resuscitative efforts had been limited chiefly to control of pain (see Monograph) and hemorrhage, and administration of plasma. Only a relatively little blood was administered; this is described forthwith. These 108 patients had, on the average, two units of plasma before the first blood sample was taken, divided as follows:

32	had	no plasma
25	had	1 unit
17	had	2 units
13	had	3 units
12	had	4 units
3	had	5 units
1	had	6 units
1	had	7 units
2	had	8 units
1	had	9 units
1	had	11 units
Total 108		

Blood administration prior to withdrawal from the patient of the first blood specimen for laboratory analysis was spread out as follows in the 27 patients of the 108 who were given whole blood under these circumstances:

13, or 12%, received ⅕ to 1 unit (500 c.c.)

10, or 9%, received 1½ to 2 units
2, or 2%, received 3 units
1, or 1%, received 4 units
1, or 1%, received 6 units

Three of these, or 3 per cent, received blood in an aid station, before admission to a forward hospital. Thus, 70 per cent of these very seriously wounded patients had had two units or less of plasma on arrival at the most forward hospital.

A summary of the average quantities of blood and of blood plasma used in resuscitating 154* of the very seriously wounded patients studied in our series is as follows:

Preoperative blood plasma	3.08 units	(average of 122 cases)
Blood plasma given during operation	1.68 units	(average of 10 cases)
Preoperative blood	1,450 c.c.	(average of 127 cases)
Blood given during operation	1,160 c.c.	(average of 95 cases)

In round numbers, our average patient had just over three units blood plasma and five blood transfusions to support him from the time of wounding until the operation was completed. It is interesting to observe that plasma was used *during* surgery in only 10 of these 154 patients.

The information concerning the cases referred to here was drawn from the shock tents of most of the hospitals of the Fifth Army and represents a broad sample of current practice in Italy over the last year of the European War. Essentially the same type of case was studied by Beecher and Burnett[3] at Anzio. In that study the average patient received 1,537 c.c. blood (three transfusions) to prepare him for and carry him through surgery. These three transfusions contrast with the five referred to previously. A notable difference between the Anzio study and Theater practice as a whole is in the time elapsed from hospital entry to start of surgery. In the Anzio study this averaged two hours and twenty-one minutes. Reference to the earlier part of this section on Evacuation Time From Wounding to Surgery will show that over the Army area as a whole the time from hospital entry to surgery varies from an average of five hours to an average of eight hours. Two differing views as to the correct preparation of wounded men for surgery are represented in these figures, the extended or the rapid. The extended required five transfusions of whole blood; the rapid, three. This has been discussed in detail elsewhere.[4]

PLASMA PROTEIN AND HEMOGLOBIN LEVELS ON FORWARD HOSPITAL ADMISSION

Consideration of plasma protein and hemoglobin levels (determined by the copper sulfate method[5]) gives a clue to the shifts that have taken place between the blood stream and the tissues (or loss into the outside world). When considered with quantitative measurements of whole blood loss, a fairly accurate picture of one consequence of the wound can be obtained.

*This number includes the 108 patients just referred to. In order to get as large a sample as possible, 49 others are added on whom we had clinical notes but did not have the admission blood chemistry data that characterized the group of 108.

Excluding the crush cases, 50 patients are shown in Table VI that had, before study, one unit* of plasma or less. These were considered shortly after their admission to the most forward hospital, before resuscitation, anesthesia, or operation had been undertaken.

Relationship of Plasma Protein and Hematocrit to Type of Wound

From Table VI it can be seen that there is no decided difference between the plasma protein levels in the two groups of wounds described there. On the other hand, the hematocrit values appear significantly higher in the abdominal group, in the direction of the hemoconcentration often found in this group. The hemoglobin loss (see the following section on Blood Loss) is smaller in the abdominal wound group than in wounds of the extremities. Maintenance of a blood volume nearer normal in the abdominal cases doubtless reduces the need and tendency for blood dilution, although of course this alone would not account for the hemoconcentration often found with the abdominal wounds.

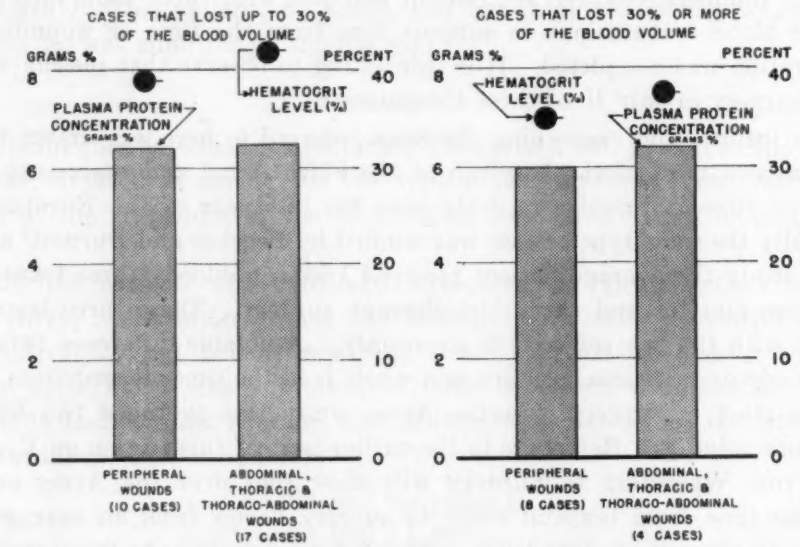


Chart 2.—Plasma protein concentration and hematocrit value in relation to type of wound and degree of blood loss. Patients received only 0 to 1 units of plasma before determination.

Relationship of Plasma Protein and Hematocrit to Blood Loss

In 40 of the 43 soldiers considered here, the blood loss was measured. (See Table VII and Chart 2.) There is a significantly lower hematocrit ("All Cases") when more than 30 per cent of the calculated normal blood volume has been lost than otherwise. The 36.0 per cent hematocrit is 23.4 per cent below the normal of 47. The fact has been observed that in the case of the plasma proteins, even when there is a loss of 30 per cent or more of the normal blood volume, the plasma protein concentration is 6.1 Gm. per cent (6.1 per cent below normal, 6.5 Gm. per cent). In other words, the hematocrit falls proportionately about four times as much as the plasma proteins. The blood appears to have been diluted by protein-rich (6.1 per cent) fluid. Where can this have

*The equivalent of 250 c.c. normal plasma diluted to 300 c.c.

TABLE VI. COMPARISON OF ABDOMINAL WITH PERIPHERAL WOUNDS*

WOUNDS	PLASMA PROTEIN (GRAMS PER CENT)	HEMATOCRIT (PER CENT CELLS)
Peripheral (25 cases)	6.2 ± 0.1	37.4 ± 1.0
Abdominal, thoracic, and thoraco-abdominal (25 cases)	6.5 ± 0.1	42.0 ± 1.0

*All patients had one unit or less of plasma before determination; excludes "crush syndrome."

come from? The evidence is too meager to justify much speculation here. However, as pointed out by Robley Evans, the axial stream of corpuscles is surrounded by a plasma envelope. This varies in thickness (and total volume) depending on certain hydraulic principles. Is it possible that the alterations in the circulation caused by the loss of 30 per cent or more of the normal volume (slowing of the peripheral circulation, for example) result in throwing an appreciable volume of plasma (with normal protein content) into the circulating blood?

Possibly protein may be brought into the circulation from the liver.

TABLE VII. PLASMA PROTEIN CONCENTRATION AND HEMATOCRIT VALUE IN RELATION TO TYPE OF WOUND AND DEGREE OF BLOOD LOSS

Patients Received only 0 to 1 Unit of Plasma Before Determination

WOUNDS	PATIENTS WHO LOST UP TO 30% OF THE BLOOD VOLUME			PATIENTS WHO LOST 30% OR MORE OF THE BLOOD VOLUME		
	PERIPHERAL WOUNDS (10 CASES)	ABDOMINAL, THORACIC, AND THORACO-ABDOMINAL WOUNDS (17 CASES)	ALL CASES (27 CASES)	PERIPHERAL WOUNDS (8 CASES)	ABDOMINAL, THORACIC, AND THORACO-ABDOMINAL WOUNDS (4 CASES)	ALL CASES (12 CASES)
Plasma protein concentration	6.4 ± 0.1	6.5 ± 0.1	6.5 ± 0.1	6.0 ± 0.1	6.4	6.1 ± 0.1
Hematocrit level	39.0 ± 1.7	43.0 ± 1.0	41.5 ± 1.0	35.0 ± 1.3	37.8	36.0 ± 1.1

Influence of Plasma Therapy Upon Plasma Protein and Hematocrit (Before the Determinations Were Made)

Only 3 of the 55 cases shown in Table VIII had included blood transfusions. These will be ignored. It is clear that the plasma protein level is not influenced by the plasma therapy (see Chart 3). But this has an important

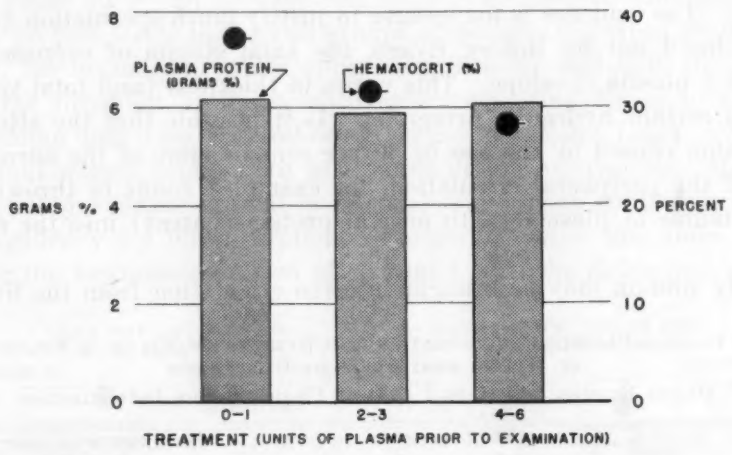
TABLE VIIIA. HEMATOCRIT AND PLASMA PROTEIN LEVELS IN ABDOMINAL WOUNDS (EXCLUSIVE OF CRUSH SYNDROME)

Values Upon Admission to Hospital; Average and Standard Errors of the Mean

TREATMENT (UNITS OF PLASMA PRIOR TO EXAMINATION)	PLASMA PROTEIN (GRAMS %)	HEMATOCRIT (%)	HOURS AFTER WOUNDING
0 to 1	6.2 ± 0.1	37.4 ± 1.0	8.5 ± 1.2
(25 cases)	(25 cases)	(25 cases)	(25 cases)
2 to 3	5.9 ± 0.1	31.9 ± 1.5	8.1 ± 1.5
(17 cases)	(17 cases)	(17 cases)	(16 cases)
4 to 6	6.1 ± 0.1	28.6 ± 1.9	9.8 ± 1.2
(13 cases)	(13 cases)	(12 cases)	(13 cases)
Total	6.1 ± 0.1	33.7 ± 0.9	8.7 ± 0.7
(55 cases)	(55 cases)	(54 cases)	(54 cases)

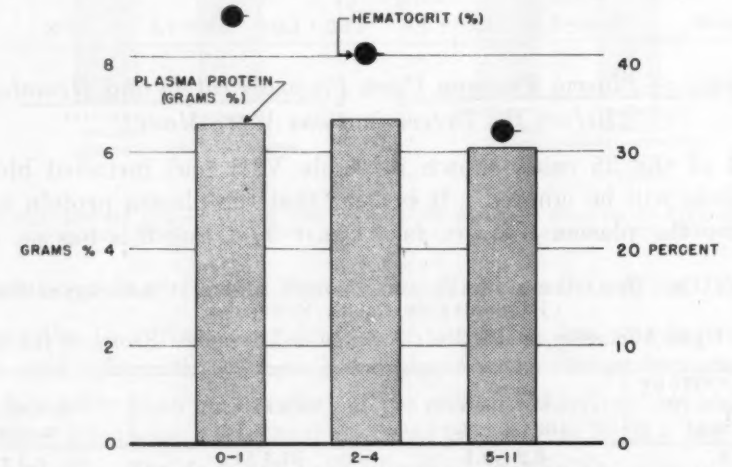
The data in this table were also broken down into two further groups: "None and Slight Shock" and "Moderate and Severe Shock." No differences were found; so these data have been omitted.

effect (or at least accompanies the condition which required the increasing volumes of plasma) on the hematocrit (see also Tables VIIIA, VIIIB, and Chart 4). The plasma protein, hematocrit, and time after wounding were analyzed in regard to shock, the data being broken up into two groups where no shock and slight shock were grouped together, as were moderate and severe shock. No important differences were found between the two groups.



HOURS AFTER WOUNDING	8.5	8.1	9.8	HOURS AFTER WOUNDING
CASES	25	17	13	CASES

Chart 3.—Hematocrit and plasma protein levels; peripheral wounds, exclusive of crush syndrome; values upon admission to hospital; average. Note that the data in the table were also broken down into two further groups: "none and slight shock" and "moderate and severe shock." No differences were found, so these data have been omitted.



HOURS AFTER WOUNDING	6.3	7.8	12.2	HOURS AFTER WOUNDING
CASES	11	5	2	CASES

Chart. 4.—Hematocrit and plasma protein levels; abdominal wounds; values upon admission to hospital, averages.

TABLE VIIIA. HEMATOCRIT AND PLASMA PROTEIN LEVELS IN ABDOMINAL WOUNDS
Values Upon Admission to Hospital; Averages and Standard Errors of the Mean

TREATMENT (UNITS OF PLASMA PRIOR TO DETERMINATION)	HEMATOCRIT (%)	PLASMA PROTEIN (GRAMS %)	HOURS AFTER WOUNDING
0 to 1 (11 cases)	44.1 ± 1.8	6.6 ± 0.2	6.3 ± 1.4
2 to 4 (5 cases)	40.2 ± 4.3	6.7 ± 0.3	7.8 ± 3.1
5 to 11	32.2 (2 cases)	6.1 (3 cases)	12.2 (2 cases)
Total	41.6 ± 1.9 (18 cases)	6.6 ± 0.1 (19 cases)	6.8 ± 1.3 (16 cases)

TABLE VIIIB. HEMATOCRIT AND PLASMA PROTEIN LEVELS IN THORACIC WOUNDS
Admission Values; Averages and Standard Errors of Means

TREATMENT (UNITS OF PLASMA PRIOR TO DETERMINATION)	PLASMA PROTEIN (GRAMS %)	HEMATOCRIT (%)	HOURS AFTER WOUNDING
0 to 1 (8 cases)	6.5 ± 0.2	40.0 ± 1.2	7.9 ± 2.6
2 to 5 (7 cases)	6.6 ± 0.2	35.4 ± 1.8	7.2 ± 1.7
Total (15 cases)	6.5 ± 0.1	37.8 ± 1.2	7.6 ± 1.4

Relationship of Plasma Protein and Hematocrit to Degree of Shock

The plasma protein and hematocrit levels were considered with regard to their clinical condition in 100 badly wounded patients on admission to the forward hospital (crush cases excluded) (see Table IX and Chart 5). The fall in plasma protein is probably significant as the cases are grouped here; the fall in hematocrit is definitely significant. No sign of hemoconcentration is present here. When the cases are divided according to location of wound, there is no significant fall in plasma protein in the peripheral wounds with relation to degree of shock. The abdominal wounds show up differently (see Table X and Chart 6).

TABLE IX. AVERAGE HEMATOCRIT AND PLASMA PROTEIN LEVELS IN DIFFERENT DEGREES OF SHOCK (ADMISSION LEVELS)
All Types of Cases, Exclusive of Crush Syndrome

FACTOR	NO SHOCK (15 CASES)	SLIGHT SHOCK (26 CASES)	MODERATE SHOCK	SEVERE SHOCK	TOTAL
Plasma protein (Grams %)	6.6 ± 0.1	6.4 ± 0.1	6.2 ± 0.1 (34 cases)	6.0 ± 0.1 (25 cases)	6.3 ± 0.1 (100 cases)
Hematocrit (%)	42.5 ± 1.7	38.4 ± 1.5	34.6 ± 1.0 (33 cases)	31.5 ± 1.5 (24 cases)	36.1 ± 0.8 (98 cases)

In the no shock-slight shock group the plasma concentration is possibly to be accounted for by weeping of the irritated peritoneal surfaces, fluid being released which contains less protein than that of the plasma. As shock becomes moderate or severe, probably due to greater blood loss, the plasma protein falls to a figure like that for extremity wounds, with hemodilution overcoming the effects of exudation.

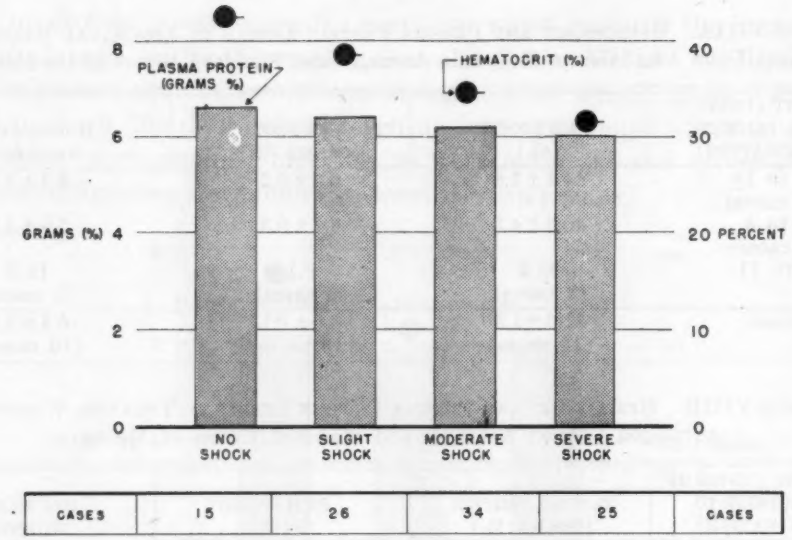
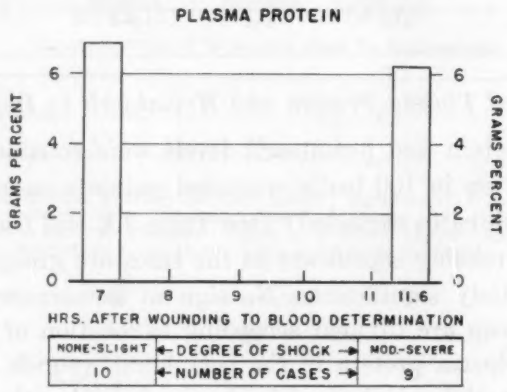


Chart 5.—Average hematocrit and plasma protein levels in different degrees of shock, admission levels; all types of cases, exclusive of crush syndrome.



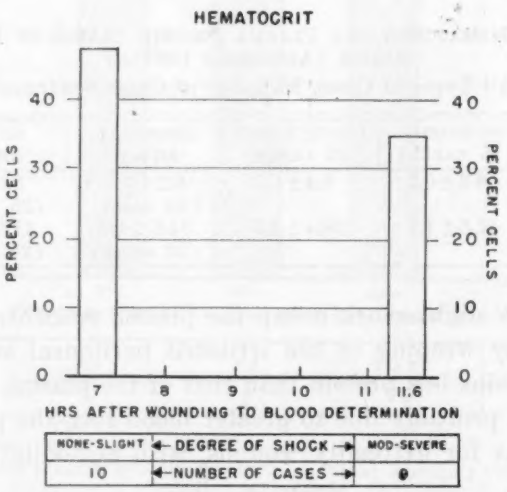


Chart 6.—Abdominal wounds (hospital admission data).

TABLE X. ABDOMINAL WOUNDS; HOSPITAL ADMISSION DATA

	DEGREE OF SHOCK	
	NONE TO SLIGHT	MODERATE TO SEVERE
Plasma protein (Grams %)	6.9 ± 0.1 (10 cases)	6.1 ± 0.2 (9 cases)
Hematocrit (% cells)	47.0 ± 1.6 (10 cases)	34.9 ± 1.8 (8 cases)
Hours after wounding	7.0 ± 1.5 (10 cases)	11.6 ± 3.2 (9 cases)

Data have been presented which indicate that the plasma protein and hematocrit values can vary independently.

BLOOD LOSS (VOLUME AND HEMOGLOBIN)

The quantity of blood a wounded man can lose and yet recover has generally been underestimated. One reason for this is the fact, well shown in the prolonged campaigns of the Mediterranean Theater, that robust young soldiers will tolerate surgery well long before their blood volume or even blood pressure has been restored to normal. (The concept of restoration of the shocked man to normal as a preliminary to surgery is based upon a false premise. Full organic restoration probably takes up to days to achieve.) A good response of a young wounded man to treatment is by no means admissible evidence that the circulatory system has been restored to normal. There is a great factor of safety here. These points have been discussed elsewhere.*

In the belief that an accurate measurement of the blood loss of wounded men, as they arrive at the most forward hospital, would emphasize the importance of whole blood administration to the wounded, such studies were carried out. In addition to this practical point, the results have shown in a useful way the almost quantitative relationship between blood loss and degree of shock, long recognized but always in need of all the support possible in order to outride the ever recurring storms arising from suggestions that the cause of shock is mysterious and to be explained by toxins or the breakdown of some vague but vital force.

The degree of wound shock, as we saw it in men injured in battle, precisely paralleled the blood loss. Conversely, clinical recovery from shock resulted promptly from the administration of whole blood. Although we made intensive search at the bedside of thousands of wounded men throughout the shock tents of Italy, we never found a clear case of irreversible shock, so easily spoken of in published articles on this subject. To be sure, we were unable, in the case of the soldier who had both thighs blown off just outside our tent by a shell burst at Anzio, to get blood into him fast enough to save his life. He died in a very few minutes. Nor were we able to resuscitate individuals who had been so long without circulation in the central nervous system that nearly all centers appeared to be dead except the respiratory. We were not able to overcome death of organs or of nervous tissue by resuscitative effort. But to apply the term "irreversible shock" to either type of case is to use a definition that we believe has no place at the bedside, however interesting it may be as a concept, a con-

*See the section on "Resuscitation" in the Appendix of the Monograph mentioned in the footnote, page 672.

TABBLE XA. INITIAL BLOOD VOLUME DATA
Further Classification of Cases

Corrected "A"	Observed values minus all fluid received until blood volume determination was completed
Corrected "B"	Observed values minus all fluid received from time patient was evaluated (usually upon arrival at hospital) until blood volume determination was completed

All percentages represent decreases from calculated normal except those marked by asterisk, which represent increases.

cept that if held at the bedside may do real harm in providing an excuse for limiting resuscitative effort. In short, if "irreversible shock" in the usual sense was present, we missed it. If toxins caused any of the shock we saw (excepting that due to clinically apparent, overwhelming bacterial infections) we failed to recognize it. The shock we saw was caused by blood loss (or loss of fractions of the blood). It was cured by blood administration.

The blood volume was determined by Gregersen's method (see the Appendix of the Monograph mentioned in the footnote, page 672 for the details of methods used) in 67 men* shortly after they arrived at the most forward hospital, in most cases a field hospital. In our studies the normal blood volume has been considered to be 8.5 per cent of the body weight (Gregersen). The blood volume found has been recorded. But this has also been corrected by subtraction of all plasma or blood administered (following the wounding and before the determination was made). This is recorded as "Series A" to distinguish it from the uncorrected volumes. Correction "B" data is the observed blood volume less only the volume of fluid administered during the period the determination was in progress. The figures reported in the tables represent the amount of blood lost, expressed as per cent of the calculated normal blood volume (8.5 per cent of

TABLE XB. NO SHOCK (12 CASES)

CASE NUMBER	BLOOD VOLUME CHANGE (% OF NORMAL)			TOTAL HEMOGLOBIN CHANGE (% OF NORMAL)			BLOOD PRESSURE AT TIME OF DETERMINATION (MM. HG)	HOURS AFTER WOUNDING	BLOOD SUGAR (MG. %)
		CORRECTED			CORRECTED				
	OBSERVED	"A"	"B"	OBSERVED	"A"	"B"			
A-13	18.4	18.4	18.4	36.2	36.2	36.2	150/70	18¾	121
A-4	8.2	8.2	8.2	31.1	31.1	31.1	132/72	4¼	93
A-16	8.2	10.5	8.2	12.2	12.2	12.2	130/70	5¼	139
134	7.8	11.3	7.8	3.8	3.8	3.8	120/76	15¼	–
A-19	31.9	31.9	31.9	42.5	42.5	42.5	116/78	8¼	167
A-22	2.8	2.8	2.8	11.5*	11.5*	11.5*	140/30	1½	110
A-23	17.0*	17.0*	17.0*	13.3*	13.3*	13.3*	128/80	4½	127
124	15.3*	2.8	2.8	14.7*	1.6	1.6	120/64	10¼	–
91	26.0	37.7	37.7	43.1	52.9	52.9	108/78	2¾	–
102	21.3	36.9	29.1	31.1	39.0	39.0	150/80	3¼	–
A-24	0.3	10.3	10.3	4.1*	6.4	6.4	110/70	4½	140
A-39	7.1	7.1	7.1	20.5	20.5	20.5	124/72	4	184

*All percentages represent decreases except those marked, which represent increases.
Case A-27 is omitted because of probable technical error.

*The blood volume was actually determined in 71 patients, but one case was excluded because of probable technical error; three others were excluded from the present discussion since they represent special situations not common to the group: two crush syndromes (Cases 93 and 124) and a head injury (A-7).

body weight) in each case. In the case of total hemoglobin, loss corrections "A" and "B" are essentially the same because, with rare exceptions, blood was not administered before the patient reached the forward hospital and the blood volume measured. See Tables XA, XB, XC, XD, XE, XF, and XG.

TABLE XC. SLIGHT SHOCK (20 CASES)

CASE NUMBER	BLOOD VOLUME CHANGE (% OF NORMAL)			TOTAL HEMOGLOBIN CHANGE (% OF NORMAL)			BLOOD PRESSURE AT TIME OF DETERMINATION (MM. HG)	HOURS AFTER WOUNDING	BLOOD SUGAR (MG. %)
	OBSERVED	CORRECTED "A"	CORRECTED "B"	OBSERVED	CORRECTED "A"	CORRECTED "B"			
144	8.8*	6.7	1.5	30.0	36.6	36.6	90/62	12¼	-
140	16.8*	1.1	1.1	11.7*	5.8	5.8	100/60	4½	141
145	8.4	15.7	12.1	27.8	30.7	30.7	100/50	9	-
141	20.2	25.5	25.5	34.7	39.1	39.1	100/60	7	131
A-25	18.7	22.3	18.7	15.1	15.1	15.1	126/80	3¼	140
A-26	7.4	7.4	7.4	23.1	23.1	23.1	110/70	4	196
A-40	3.5*	3.5*	3.5*	5.5	5.5	5.5	100/64	3½	126
128	6.2*	49.8	32.6	9.7	39.8	39.8	110/80	6½	184
127	39.8	59.4	44.2	63.1	65.9	65.9	90/40	11	-
A-17	41.5	63.9	49.0	61.6	69.1	69.1	140/60	3½	201
A-20	33.9	37.9	33.9	56.6	56.6	56.6	92/50	13¼	145
113	14.9	20.2	20.2	23.4	28.2	28.2	94/58	3¼	149
111	2.7	7.1	7.1	5.1	5.1	5.1	120/80	14½	157
83	13.1*	3.3	0.8	3.9	16.1	16.1	130/70	5¼	-
A-8	14.8	14.8	14.8	23.3	23.3	23.3	108/70	10	-
A-10	3.7	3.7	3.7	28.4	28.4	28.4	108/74	11½	-
A-11	29.9	33.4	29.9	37.4	37.4	37.4	110/76	5¼	79
A-1	9.3	17.4	14.0	17.8	22.6	22.6	116/60	2¾	155
A-2	2.3	2.3	2.3	9.6	9.6	9.6	114/62	4¼	170
A-5	25.3	25.3	25.3	35.6	35.6	35.6	120/86	8	106

*All percentages represent decreases except those marked, which represent increases.

TABLE XD. MODERATE SHOCK (21 CASES)

CASE NUMBER	BLOOD VOLUME CHANGE (% OF NORMAL)			TOTAL HEMOGLOBIN CHANGE (% OF NORMAL)			BLOOD PRESSURE AT TIME OF DETERMINATION (MM. HG)	HOURS AFTER WOUNDING	BLOOD SUGAR (MG. %)
	OBSERVED	CORRECTED "A"	CORRECTED "B"	OBSERVED	CORRECTED "A"	CORRECTED "B"			
A-9	25.9	35.0	25.9	49.1	49.1	49.1	112/70	7½	-
A-12	11.3	20.4	20.4	23.5	35.6	35.6	104/70	2¾	164
A-14	32.6	40.2	32.6	50.3	50.3	50.3	100/80	5¼	93
A-15	29.2	44.4	29.2	53.5	53.5	53.5	104/70	7	143
126	30.9	32.3	32.3	43.0	44.4	44.4	100/60	2¾	183
A-3	5.4*	2.9*	2.9*	5.8	8.3	8.3	136/90	4	185
A-6	24.2	29.8	24.2	38.4	38.4	38.4	118/64	3¼	208
129	21.7	30.9	21.7	44.2	44.2	44.2	120/64	5½	191
A-18	42.7	46.6	42.7	61.7	61.7	61.7	30/20	8¼	134
53	10.6	22.9	22.9	29.6	37.8	37.8	80/40	3¼	-
107	20.7	78.6	68.9	49.5	77.6	77.6	80/50	3	374
A-30	31.8	54.1	40.7	57.8	66.7	66.7	88/40	5¼	198
A-31	10.2	17.8	10.2	26.9	26.9	26.9	80/52	10	180
A-32	25.4	37.9	29.5	42.6	46.8	46.8	80/40	7½	115
A-33	2.9	28.4	25.3	21.7	40.6	40.6	90/50	5¼	175
A-37	41.6	52.4	52.4	62.4	62.4	62.4	120/68	3	136
A-35	37.5	41.9	37.5	55.1	55.1	55.1	86/66	-	159
143	3.4*	13.9	1.8*	22.5	24.0	24.0	80/54	6	203
148	5.2	24.8	14.9	39.6	45.8	45.8	74/20	12	175
142	25.7	31.9	27.0	41.9	43.0	43.0	110/70	6¾	210
A-36	34.1	38.6	38.6	56.8	56.8	56.8			

*All percentages represent decreases except those marked, which represent increases.

TABLE XE. SEVERE SHOCK (16 CASES)

CASE NUMBER	BLOOD VOLUME CHANGE (% OF NORMAL)			TOTAL HEMOGLOBIN CHANGE (% OF NORMAL)			BLOOD PRESSURE AT TIME OF DETERMINATION (MM. HG)	HOURS AFTER WOUNDING	BLOOD SUGAR (MG. %)
	OBSERVED	CORRECTED "A"	CORRECTED "B"	OBSERVED	CORRECTED "A"	CORRECTED "B"			
147	6.5	24.1	14.3	37.5	42.7	42.7	80/48	13¾	165
149	2.3	31.3	9.8	26.1	32.7	32.7	48/ ?	17¾	115
139	19.3	75.7	23.3	50.5	70.7	54.5	Not measurable	9	-
A-28	9.2	28.0	9.2	38.7	38.7	38.7	64/20	6¾	218
A-29	28.2	54.9	37.1	54.7	63.6	63.6	80/38	5¾	382
125	21.3	33.0	29.1	44.9	52.7	52.7	72/58	23	125
A-34	12.8*	16.6	8.2	0	19.0	19.0	80/68	?	125
122	34.4	55.0	48.2	45.9	58.4	58.4	50/30	4	87
A-38	24.6	58.3	48.7	42.0	66.1	66.1	0	?	133
A-21	46.7	71.0	54.8	75.6	83.8	83.8	68/50	4¼	234
108	25.5	38.9	30.0	61.8	64.1	64.1	58/ 0	3½	372
93	11.7	34.0	30.3	12.0*	2.6*	2.6*	0	14½	-
110	35.7	37.6	37.6	45.7	47.4	47.4	0	¾	-
100	28.4	69.0	65.0	44.1	76.6	76.6	80/50	4½	-
130	31.3	51.6	40.5	51.6	62.0	62.0	60/20	5	272
131	29.8	43.6	39.0	45.1	54.3	54.3	40/20	5¾	177
112								11¾	216

*All percentages represent decreases except those marked, which represent increases.

TABLE XF. BLOOD PRESSURE AND BLOOD LOSS

CASE NUMBER	BLOOD PRESSURE AT TIME OF OPERATION (MM. HG)	SEVERITY OF SHOCK	BLOOD SUGAR (MG. %)	HOURS AFTER WOUNDING	LOSS OF BLOOD (% OF CALCULATED NORMAL)			LOSS OF TOTAL CIRCULATING HEMOGLOBIN	
					FOUND	CORRECTION "A"	CORRECTION "B"	FOUND (GM.)	CORRECTION "B"
A-3	133/90	Mod. sev.	185	4	5.4*	2.9*	2.9*	896.6	8.3
A-26	110/70	Slight	196	4	7.4	7.4	7.4	711.6	23.1
A-4	132/72	0	93	4¼	8.2	8.2	8.2	639.0	31.1
108	58/0	Severe	372	3½	25.5	38.9	30.0	341.9	64.1
A-2	114/62	Slight	170	4¼	2.3	2.3	2.3	922.0	9.6
A-33	90/50	Mod. sev.	175	5¼	2.9	28.4	25.3	585.5	40.6
A-16	130/70	0	139	5¼	8.2	10.5	8.2	895.8	12.2
113	94/58	Slight	149	3¼	14.9	20.2	20.2	573.1	28.2
A-32	80/40	Mod. sev.	115	7½	25.4	37.9	29.5	549.8	46.8
A-7		Head (?) injury	315	½	31.6	31.6	31.6	540.6	47.0
93	0	Severe	-	14½	11.7	34.0	30.3	1203.8	2.6*
A-22	140/80	None	110	1½	2.8	2.8	2.8	1200.6	11.5*
A-13	150/70	None	121	19¾	18.4	18.4	18.4	555.0	36.2
A-18	30/20	Mod. sev.	134	8¼	42.7	46.6	42.7	398.4	61.7
144	90/62	Slight	-	12¼	8.8*	6.7	1.5	542.8	36.6
A-35	86/66	Mod. sev.	159	-	37.5	41.9	37.5	415.2	55.1
A-8	108/70	Mild	-	10	14.8	14.8	14.8	667.4	23.3
143	80/54	Mod. sev.	203	6	3.4*	13.9	1.8*	790.8	24.0
147	80/48	Severe	165	13¾	6.5	24.1	14.3	510.4	42.7
A-20	92/50	Slight	145	13¼	33.9+	37.9	33.9+	429.1	56.6
111	120/80	Slight	157	14½	2.7	7.1	7.1	851.8	5.1
140	100/60	Slight	141	4½	16.8*	1.1	1.1	1002.2	5.8
A-29	80/38	Severe	382	5¾	28.2	54.9	37.1	407.0	63.6
A-37	120/68	Mod. sev.	136	3	41.6	52.4	52.4	418.2	62.4
A-40	100/64	Slight	126	3½	3.5	3.5*	3.5*	899.4	5.5
126	100/60	Mod. sev.	183	2¾	30.9	32.3	32.3	666.6	44.4
127	90/40	Mild	-	11	39.8	59.4	44.2	331.2	65.9
A-28	64/20	Severe	218	6¾	9.2	28.0	9.2	522.7	38.7
A-19	116/78	None	167	8¼	31.9	31.9	31.9	579.3	42.5
A-39	124/72	None	184	4	7.1	7.1	7.1	786.4	20 5

*All percentages represent decreases except those marked, which represent increases.

TABLE XG. BLOOD PRESSURE AND BLOOD LOSS

CASE NUMBER	BLOOD PRESSURE AT TIME OF OPERATION (MM. HG)	SEVERITY OF SHOCK	BLOOD SUGAR (MG. %)	HOURS AFTER WOUNDING	LOSS OF BLOOD (% OF CALCULATED NORMAL)			LOSS OF TOTAL CIRCULATING HEMOGLOBIN	
					FOUND	CORRECTION "A"	CORRECTION "B"	FOUND (GM.)	CORRECTION "B"
148	72/20	Mod. sev.	175	12	5.2	24.8	14.9	493.2	45.8
145	100/50	Slight		9	8.4	15.7	12.1	785.0	30.7
131	40/20	Severe	177	5¾	29.8	43.6	39.0	477.5	54.3
110	0	Severe	-	¾	35.7	37.6	37.6	553.5	47.4
124	120/64	None	-	10¼	15.3	2.8	2.8	1012.5	1.6
A-27	114/80	None	125	5¼	32.7	32.7*	32.7*	1170.6	48.4*
A-12	104/70	Mod. sev.	164	2¾	11.3	20.4	20.4	676.2	35.6
130	60/20	Severe	272	5	31.3	51.6	40.5	410.9	62.0
100	80/50	Severe	-	4½	28.4	69.0	65.0	551.3	76.6
A-15	104/70	Mod. sev.	143	7	29.2	44.4	29.2	488.3	53.5
129	120/64	Mod. sev.	191	5½	21.7	30.9	21.7	485.6	44.2
A-30	88/40	Mod. sev.	198	5¼	31.8	54.1	40.7	378.7	66.7
A-38	0	Severe	133	?	24.6	58.3	48.7	482.2	66.1
A-23	120/80	None	127	4½	17.0	17.0*	17.0*	1120.7	13.3*
53	80/40	Mod. sev.	106	3¼	10.6	22.9	22.9	689.2	37.8
A-5	120/86	Mild	106	8	25.3	25.3	25.3	604.4	35.6
A-11	110/76	Mild	79	5¼	29.9	33.4	29.9	716.4	37.4
A-17	140/60	Slight	201	3½	41.5	63.9	49.0	411.6	69.1
122	50/30	Severe	87	4	34.4	55.0	48.2	632.3	58.4
A-21	68/50	Severe	234	4½	46.7	71.0	54.8	240.4	83.8
91	108/78	0	-	2¾	26.0	37.7	37.7	464.3	52.9
149	48/ ?	Severe	115	8¼	2.3	31.3	9.8	693.3	32.7
A-6	118/64	Mod. sev.	208	3¼	24.2	29.8	24.2	479.7	38.4
142	110/70	Mod. sev.	210	6¾	25.7	31.9	27.0	521.3	43.0
139	0	Severe	-	9	19.3	75.7	23.3	491.0	54.5
125	72/58	Severe	125	23	21.3	33.0	29.1	562.2	52.7
A-14	100/80	Mod. sev.	93	5¼	32.6	40.2	32.6	522.7	50.3
134	120/76	None	-	15¼	7.8	11.3	7.8	1098.9	3.8
A-1	116/60	Slight	155	2¾	9.3	17.4	14.0	967.2	22.6
128	110/80	Slight	184	6½	6.2	49.8	32.6	837.8	39.8
102	150/80	0	-	3¼	21.3	36.9	29.1	702.8	39.0
141	100/60	Slight	131	7	20.2	25.5	25.5	648.5	39.1
A-25	126/80	Slight	140	3¼	18.7	22.3	18.7	923.5	15.1
A-9	112/70	Mod. sev.	-	7½	25.9	35.0	25.9	449.9	49.1
A-31	80/52	Mod. sev.	180	10	10.2	17.8	10.2	778.8	26.9
107	80/50	Mod. sev.	374	3	20.7	78.6	68.9	419.2	77.6
A-10	108/74	Mild	-	11½	3.7	3.7	3.7	842.5	28.4
A-24	110/70	None	140	4½	0.3	10.3	10.3	832.5	6.4
83	130/70	Slight	-	5¼	13.1	3.3	0.8	941.1	16.1
A-34	80/68	Severe	125	26¾	12.8	16.6	8.2	952.8	19.0
A-36		Mod. sev.				38.6	8.6		56.8

*All percentages represent decreases except those marked, which represent increases.

TABLE XI. RELATIONSHIP BETWEEN BLOOD VOLUME LOSS AND TYPE OF WOUND

Figures Represent Blood Loss Expressed as Per Cent of the Calculated Normal Blood Volume; All Values Before Operation and Anesthesia

TYPE OF WOUND	FOUND	CORRECTION "A"	CORRECTION "B"
Peripheral wounds (32 cases)	20.8 ± 3.0	34.2 ± 3.2	28.2 ± 3.1
Abdominal wounds (13 cases)	7.6 ± 3.6	21.3 ± 6.2	16.4 ± 5.5
Thoracic wounds (14 cases)	17.9 ± 2.6	28.6 ± 4.6	21.4 ± 2.3
Thoracoabdominal wounds (6 cases)	6.6 ± 6.8	13.7 ± 5.5	10.3 ± 6.2
Total (65 cases)	16.2 ± 1.9	28.5 ± 2.5	22.7 ± 2.1

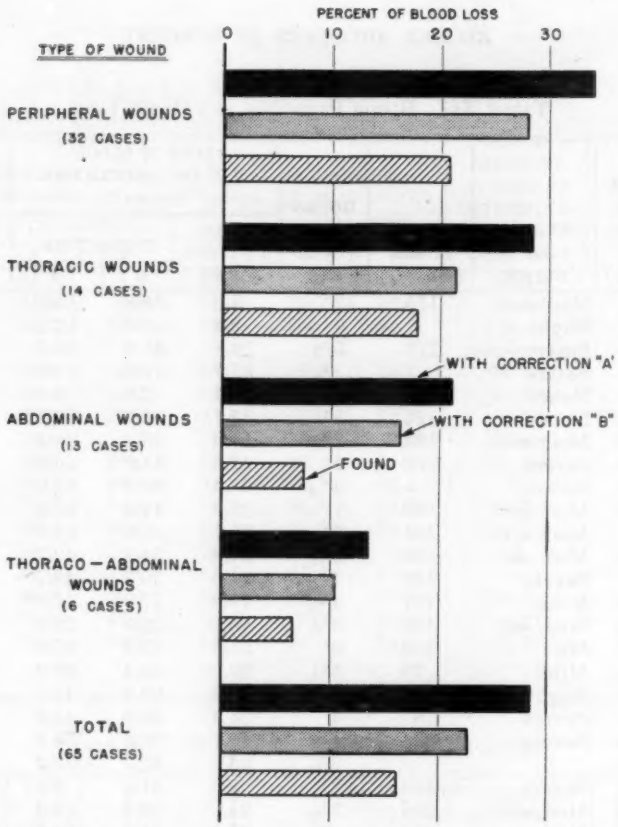


Chart 7.—Relationship between blood loss and type of wound. Figures represent blood loss expressed as per cent of the calculated normal blood volume; all values before operation and anesthesia.

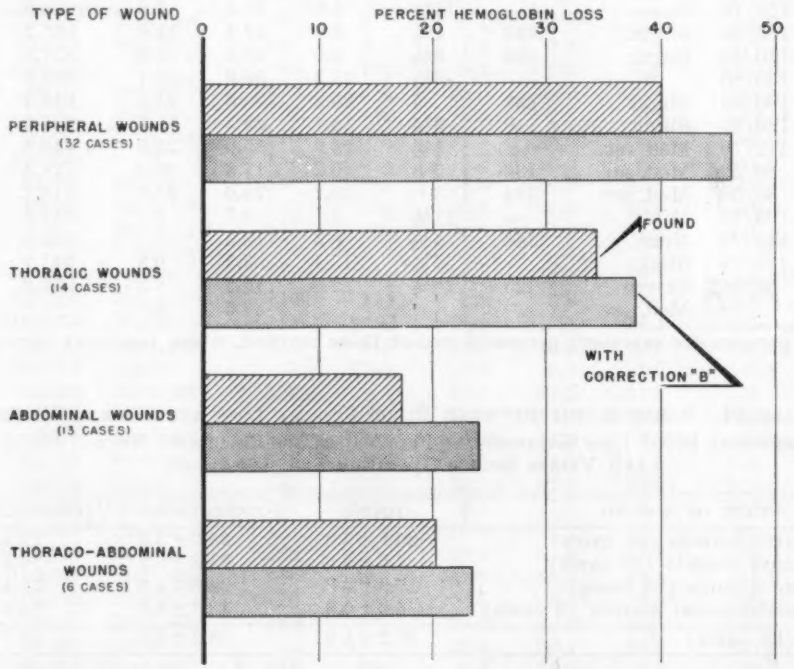


Chart 8.—Relationship between hemoglobin loss and type of wound. Figures represent hemoglobin loss expressed as per cent of the calculated normal total hemoglobin in the circulation; all values before operation and anesthesia.

Relationship of Blood Loss to Type of Wound

Fifty-nine of the patients suffered primarily from a single major wound—abdomen, chest, or peripheral wound—and could be accurately classified (see Tables XI and XII, and Charts 7 and 8).

TABLE XII. RELATIONSHIP BETWEEN HEMOGLOBIN LOSS AND TYPE OF WOUND
Figures Represent Hemoglobin Loss Expressed as Per Cent of the Calculated Normal Total Hemoglobin in the Circulation; All Values Before Operation and Anesthesia

TYPE OF WOUND	FOUND	CORRECTION "B"
Peripheral wounds (32 cases)	40.0 ± 3.4	46.0 ± 3.1
Abdominal wounds (13 cases)	17.3 ± 6.0	24.0 ± 6.4
Thoracic wounds (14 cases)	34.4 ± 3.2	37.8 ± 3.2
Thoracoabdominal wounds (6 cases)	20.3 ± 6.5	23.6 ± 6.3
Total (65 cases)	32.5 ± 2.5	37.8 ± 2.6

The huge standard errors present in several instances reflect the wide variation in the results found. At first glance the loss of blood volume appears to be greater in the peripheral wounds than it is in the abdominal, for example. This may be true, but the data are not extensive enough to show it, the true state of affairs possibly being masked by the small number of cases, the wide variability in blood loss from one case to another, and the dilution of the blood volume postwounding by the movement of fluid from the tissues to the blood stream. A more revealing situation can probably be found in the hemoglobin loss. Here there is a significantly greater hemoglobin loss in men with peripheral wounds than in those with abdominal wounds. In this case, the facts are not obscured by hemodilution. This difference shown here fits in with the demonstration made previously that patients with compound fractures of long bones or traumatic amputations constitute a higher percentage in the severe-shock group than do those with abdominal wounds. While the following data

TABLE XIII. RELATIONSHIP BETWEEN BLOOD LOSS AND TYPE OF WOUND IN PATIENTS WHO HAD RECEIVED 0 TO 1 UNIT OF PLASMA BEFORE THE DETERMINATION
Figures Represent Blood Loss Expressed as Per Cent of the Calculated Normal; All Values Before Operation and Anesthesia

TYPE OF WOUND	LOSS OF BLOOD VOLUME (CORRECTION "A")	LOSS OF TOTAL HEMOGLOBIN (CORRECTION "B")
Peripheral wounds (18 cases)	23.9 ± 3.9	38.0 ± 4.3
All other wounds (22 cases)	15.2 ± 2.9	22.5 ± 3.8
Total (40 cases)	19.1 ± 2.4	29.5 ± 3.1

TABLE XIV. EXTREMITY WOUNDS; LOSS OF CIRCULATING BLOOD AND TOTAL CIRCULATING HEMOGLOBIN DETERMINED VALUES MINUS ALL BLOOD AND PLASMA REPLACEMENTS
Per Cent Lost From Calculated Normal

	NO FRACTURE	COMPOUND FRACTURE	TRAUMATIC AMPUTATION
Blood volume Loss "A"*	21.9 ± 8.1 (7 cases)	40.8 ± 4.2 (19 cases)	27.0 ± 3.2 (5 cases)
Hemoglobin Loss "B"	32.8 ± 7.0 (7 cases)	51.6 ± 4.2 (19 cases)	43.0 ± 3.9 (5 cases)

*Correction "A" used on blood loss "observed values less all fluid received until time blood volume determination was completed."

are few, they are pertinent to the present discussion and are presented for what they are worth (see Table XIV, and Chart 10).

The blood loss with compound fractures is greater than it is in traumatic amputation, probably due to the greater tissue damage usually found in the former case.

Table XIII (Chart 9) shows the blood and hemoglobin losses in cases selected to include only those patients who had received no more than 0 to 1 unit of plasma before the determination. The losses here are smaller than those

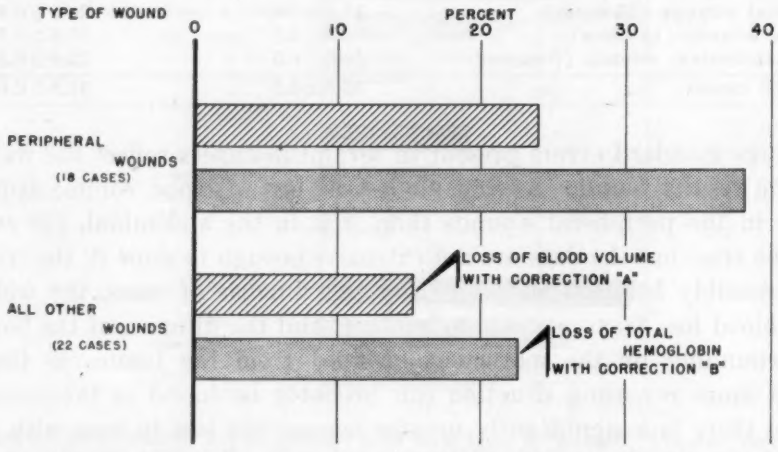


Chart 9.—Relationship between blood loss and type of wound in patients who had received only 0 to 1 unit of plasma before the determination. Figures represent blood loss expressed as per cent of the calculated normal; all values before operation and anesthesia.

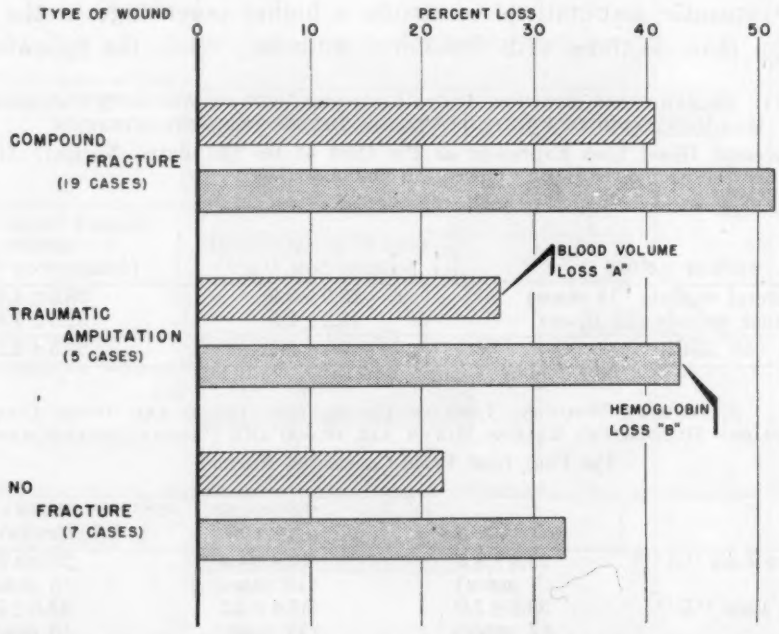


Chart 10.—Extremity wounds; loss of circulating blood and total circulating hemoglobin; determined values minus all blood and plasma replacements; per cent lost from calculated normal. Note: correction "A" used on blood loss "observed values less all fluid received until time blood volume determination was completed."

indicated in Tables XI and XII, because the group includes fewer of the patients in severe shock. All tables show a greater average loss of hemoglobin than of blood volume. This is explained by hemodilution which normally takes place after blood loss. Red blood cells are not replaced appreciably during the interval from wounding to forward hospital arrival, except by transfusion.

Time From Wounding to Blood Loss Measurement

There is no important increase in blood volume loss or in hemoglobin loss with the passage of time. A misinterpretation would probably be easy here. Quite probably those men who were suffering from continuing blood loss were, whenever this was known, given priority of evacuation and reached the hospital sooner than would otherwise have been the case (see Table XV and Chart 11). This was often supported by the somewhat greater blood loss found in those who arrived early against those who came in later.

TABLE XV. BLOOD LOSS AND TIME AFTER WOUNDING

HOURS AFTER WOUNDING	CORRECTED*BLOOD LOSS "A" (% NORMAL)	CORRECTED HEMOGLOBIN LOSS "B" (% NORMAL)
0 to 6	29.0 (41 cases)	37.5 (41 cases)
7 to 12	31.9 (17 cases)	42.3 (17 cases)
13 and up	24.7 (9 cases)	35.8 (9 cases)

*Observed values less blood and plasma administered before blood determination was completed.

Relationship of Blood Loss to Degree of Shock

It is well known that individuals, even healthy, previously normal young soldiers, do not respond alike to a given blood loss. This fact, plus the inexactness inherent in any clinical appraisal, not to go into the errors of the experimental method used—all of these things might have tended to obscure a real relationship here; that they did not is clear from Table XVI, Charts 12 and 13. The greatest blood volume loss was found in two patients in moderate and severe shock. They had lost, respectively, 78.6 and 75.7 per cent of their normal blood volume (correction "A"). Patient A-21, who had extremity wounds and was in severe shock, lost 83.8 per cent of the normal amount of his hemoglobin.

TABLE XVI. BLOOD LOSS IN SHOCK

	BLOOD LOSS (CORRECTED VALUE)*		BLOOD LOSS FOUND	
DEGREE OF SHOCK	BLOOD VOLUME (% NORMAL)	HEMOGLOBIN (% NORMAL)	BLOOD VOLUME (% NORMAL)	HEMOGLOBIN (% NORMAL)
None	14.4 ± 3.9 (11 cases)	20.0 ± 5.2 (11 cases)	10.5 ± 3.2 (11 cases)	17.4 ± 4.7 (11 cases)
Slight	20.7 ± 4.3 (20 cases)	29.7 ± 4.1 (20 cases)	11.2 ± 3.0 (20 cases)	25.0 ± 4.0 (20 cases)
Moderate	34.3 ± 3.5 (21 cases)	46.1 ± 3.4 (21 cases)	21.7 ± 2.8 (21 cases)	41.7 ± 3.3 (21 cases)
Severe	45.9 ± 4.7 (15 cases)	54.4 ± 4.3 (15 cases)	22.0 ± 3.2 (15 cases)	44.3 ± 3.0 (15 cases)

*Blood and plasma subtracted if administered following wounding and before blood volume determination was completed.

As a generalization, one can say that when one-third of the blood volume is lost, clinical shock of more than slight degree is present; when one-half is gone severe shock is present.

In individual cases 60 to 75 per cent of the corrected blood volume, or 60 to 75 per cent of the corrected total hemoglobin, may be lost with survival. See Cases A-17, A-21, A-29, A-37, A-38, 127, and 139 for examples.

Again, speaking generally, on arrival at the hospital, the percentage of hemoglobin loss is greater than the blood volume loss. This is understandable in view of the well-known mechanism for replenishing blood volume at the expense of tissue fluid. Once the readily available reserves of hemoglobin (red cells) are called into action, no mechanisms are available to cope immediately with the needs of the body, and greater falls in hemoglobin are apparent than is the case with the blood volume.

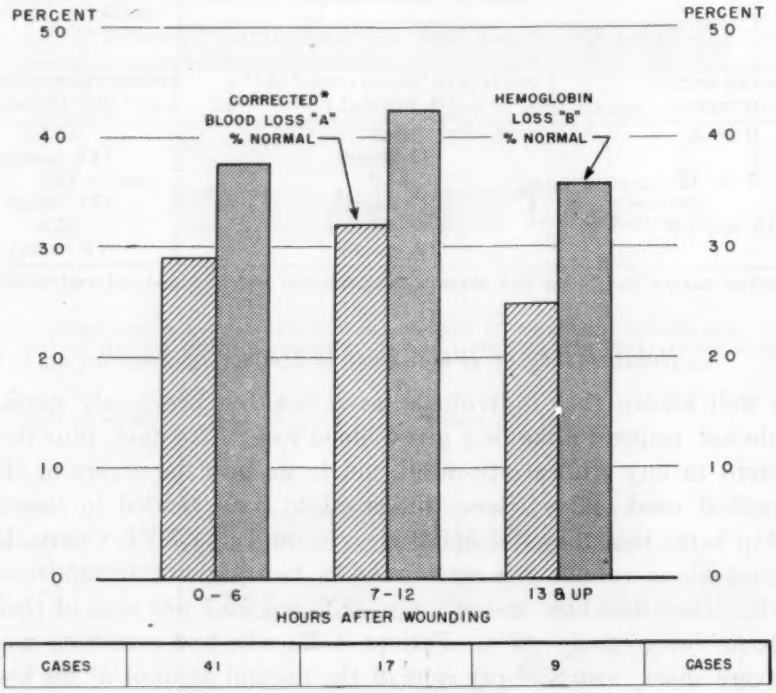


Chart 11.—Blood loss and the time after wounding (observed values less blood and plasma administered before blood determination was completed).

We have tried various schemes for handling our "shock" data. Some have attempted this by separating the effects of blood loss alone from those supposedly accounted for by "sympathico-adrenal activity." Practically, this is impossible. Moreover, the validity of any such separation, even if possible, must be questioned. Take the matter of increased glycogenolysis in shock. How is one to deal with this? After all of the recent advances in knowledge of carbohydrate metabolism, it seems to be too great a simplification to hang the explanation on the rather shaky pegs of sympathicoadrenal activity. Therefore, we take refuge in our purpose of presenting a source book, in stating our findings and leaving to postwar leisure the search for full significance.

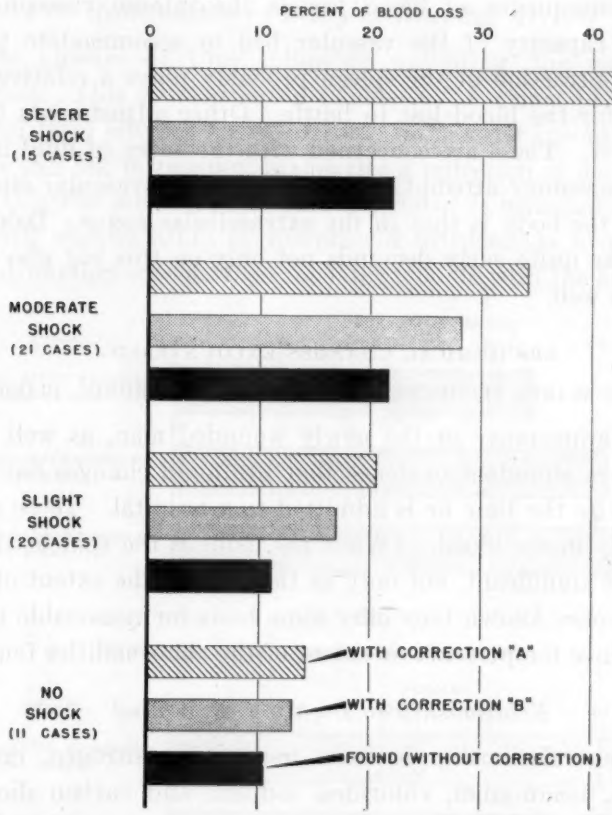


Chart 12.—Blood loss in shock. Figures represent average loss expressed as per cent of the calculated normal blood volume; determinations before operation or anesthesia.

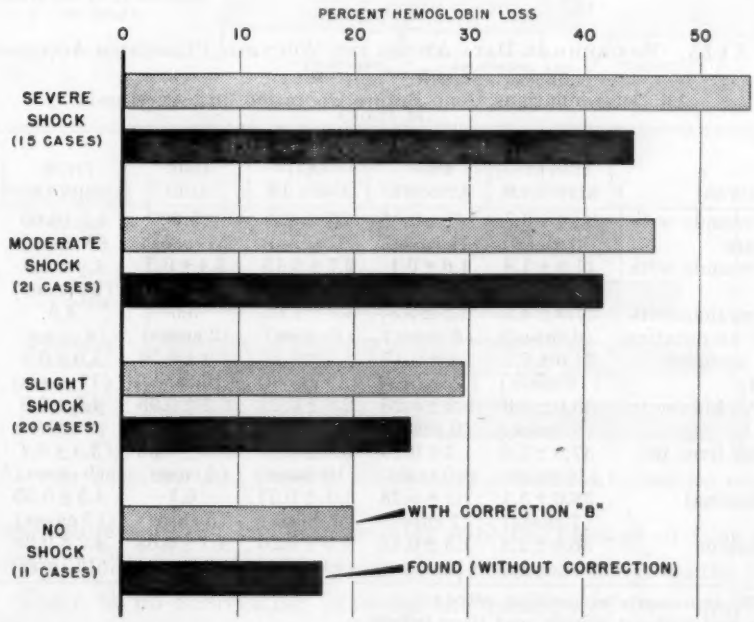


Chart 13.—Relationship between loss of hemoglobin and degree of shock. Figures represent loss of hemoglobin expressed as per cent of calculated normal total circulating hemoglobin.

One great consequence of blood loss is the intense vasoconstriction, the shrinkage of the capacity of the vascular bed to accommodate the decreased blood volume. Contraction of the spleen probably plays a relatively small role in compensating for the blood lost in battle. Other adjustments for blood loss take place, however. These are concerned with the entry of fluid into the blood vessels in a compensatory attempt. The greatest extravascular store of readily available fluid in the body is that in the extracellular space. Dehydration and oligemia may make quite early demands not only on this but also on the intracellular supply as well.

BIOCHEMICAL CHANGES ENCOUNTERED

(NITROGENOUS WASTE PRODUCTS, ELECTROLYTES, BILIRUBIN, BLOOD SUGAR)

The clinical appearance of the newly wounded man, as well as his subsequent course, offers abundant evidence that profound changes have occurred in his internal state by the time he is admitted to a hospital. To be reported here are changes chiefly in the blood. (When the urine is the vehicle, this is stated.) These changes are significant, not only as they reveal the extent of the problem at hand, but also once known they offer some basis for reasonable therapy. Several factors influence the presence or extent of the abnormalities found.

Relationship to Location of Wound

No significant relationship between nonprotein nitrogen, creatinine, uric acid, phosphorus, magnesium, chlorides, sodium, and carbon dioxide and the location of the wound has been found (for example see Table XVIA). The other data are equally "negative," and for brevity are omitted from this section.

TABLE XVIA. BIOCHEMICAL DATA AMONG THE WOUNDED, CLASSIFIED ACCORDING TO TYPE OF WOUND

All Determinations Done Before Operation and Anesthesia

WOUNDS	NON-PROTEIN NITROGEN	CREATININE	N.P.N.* CREATININE × 10	URIC ACID	PHOSPHORUS	MAGNESIUM
Peripheral wounds without fracture	39.0 ± 3.7 (11 cases)	1.7 ± 0.16 (11 cases)	2.6 ± 0.2 (11 cases)	5.0 (5 cases)	4.5 ±0.65 (6 cases)	2.3 (5 cases)
Peripheral wounds with fracture	41.0 ± 1.8 (32 cases)	1.6 ± 0.1 (31 cases)	2.7 ± 0.13 (31 cases)	4.4 ± 0.5 (19 cases)	4.9 ± 0.5 (24 cases)	2.3 ±0.13 (20 cases)
Peripheral wounds with traumatic amputation	47.0 ± 4.3 (6 cases)	1.5 ± 0.3 (6 cases)	3.7 ± 0.65 (6 cases)	5.5 (2 cases)	4.9 (4 cases)	2.0 (3 cases)
Abdominal wounds† (all cases)	34.0 ± 2.2 (19 cases)	1.4 ± 0.15 (19 cases)	2.7 ± 0.12 (19 cases)	4.9 ± 0.59 (16 cases)	3.9 ± 0.3 (17 cases)	2.0 ± 0.1 (16 cases)
Patients with kidney injury	35.0 ± 2.9 (9 cases)	1.5 ± 0.25 (9 cases)	2.6 ± 0.29 (9 cases)	6.5 ± 0.99 (6 cases)	4.0 ± 0.5 (9 cases)	2.0 ± 0.12 (7 cases)
Patients with liver injury	37.0 ± 3.0 (10 cases)	1.3 ± 0.10 (10 cases)	3.0 ± 0.23 (10 cases)	5.8 ± 0.98 (6 cases)	3.9 ± 0.4 (9 cases)	2.0 ± 0.1 (6 cases)
Thoracoabdominal wounds*	38.0 ± 3.1 (7 cases)	1.5 ± 0.28 (7 cases)	3.0 ± 0.37 (7 cases)	6.1 (5 cases)	4.5 ± 0.55 (7 cases)	2.0 (5 cases)
Thoracic wounds	36.0 ± 2.5 (14 cases)	1.3 ± 0.15 (14 cases)	2.9 ± 0.26 (14 cases)	4.1 ± 0.63 (8 cases)	4.2 ± 0.28 (13 cases)	1.9 ± 0.10 (11 cases)

*N.P.N. represents nonprotein nitrogen.

†With and without kidney and liver injury.

Relationship to Delay in Hospital Arrival

With the passage of time following wounding, the nonprotein nitrogen blood level rises. This upward swing (Table XVII, Chart 14) of the nonprotein nitrogen blood level offers a basis for some interesting speculation, out of place here; but one can ask in passing, is this rise a reflection of decreased renal blood flow? Does this rise mean that renal impairment is initiated by the wound and continues, with accumulation of nonprotein nitrogenous products? Does this presumed malfunction set the stage for later trouble with the kidneys?

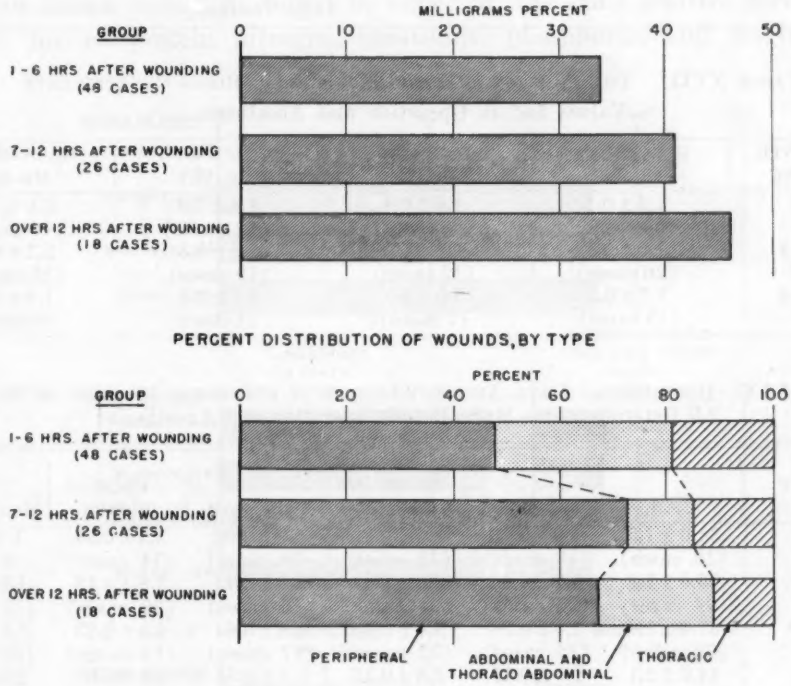


Chart 14.

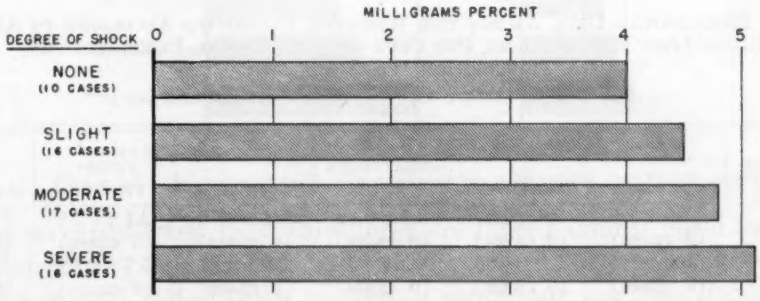


Chart 15.—Admission uric acid levels divided according to clinical condition of patient.

The creatinine does not rise significantly with the passage of time preceding hospital entry; neither do the uric acid, phosphorus, or magnesium (see Table XVIII). There is no correlation between the passage of time and the blood levels of chlorides, sodium, or carbon dioxide.

TABLE XVII. RELATIONSHIP OF NONPROTEIN NITROGEN BLOOD LEVEL TO THE PASSAGE OF TIME
Values Before Operation and Anesthesia

HOURS AFTER WOUNDING	NONPROTEIN NITROGEN (MG. %)	DISTRIBUTION OF WOUNDS IN THESE CASES
1 to 6	34.2 ± 1.1 (48 cases)	48% Peripheral 33% Abdominal and thoracoabdominal 19% Thoracic
7 to 12	41.2 ± 1.7 (26 cases)	73% Peripheral 12% Abdominal and thoracoabdominal 15% Thoracic
13 and up	46.3 ± 3.2 (18 cases)	67% Peripheral 22% Abdominal 11% Thoracic

TABLE XVIII. THE PASSAGE OF TIME AND SEVERAL BLOOD CONSTITUENTS
Values Before Operation and Anesthesia

HOURS AFTER WOUNDING	CREATININE (MG. %)	URIC ACID (MG. %)	PHOSPHORUS (MG. %)	MAGNESIUM (MG. %)
1 to 6	1.3 ± 0.1 (50 cases)	4.5 ± 0.4 (38 cases)	4.4 ± 0.3 (49 cases)	2.1 ± 0.1 (41 cases)
7 to 12	1.6 ± 0.1 (26 cases)	4.7 ± 0.5 (15 cases)	4.8 ± 0.3 (19 cases)	2.1 ± 0.1 (15 cases)
13 to 24	1.7 ± 0.2 (19 cases)	5.9 ± 0.7 (7 cases)	4.2 ± 0.5 (11 cases)	1.8 ± 0.1 (9 cases)

TABLE XIX. BIOCHEMICAL DATA AMONG WOUNDED IN DIFFERENT DEGREES OF SHOCK
All Determinations Made Before Operation and Anesthesia

DEGREE OF SHOCK	N.P.N.	CREATININE	N.P.N. CREATININE × 10	URIC ACID	PHOSPHORUS	MAGNESIUM
None	34.0 ± 1.5 (18 cases)	1.0 ± 0.05 (18 cases)	3.3 ± 0.12 (18 cases)	4.0 ± 0.62 (10 cases)	3.3 ± 0.24 (14 cases)	1.7 ±0.05 (11 cases)
Slight	35.0 ± 1.8 (24 cases)	1.3 ± 0.09 (24 cases)	2.9 ± 0.17 (24 cases)	4.5 ± 0.41 (16 cases)	3.8 ± 0.18 (20 cases)	1.9 ± 0.06 (17 cases)
Moderate	37.0 ± 1.6 (32 cases)	1.4 ± 0.08 (32 cases)	2.8 ± 0.15 (32 cases)	4.8 ± 0.61 (17 cases)	4.3 ± 0.23 (24 cases)	2.0 ± 0.09 (20 cases)
Severe	44.0 ± 2.1 (24 cases)	2.1 ± 0.15 (23 cases)	2.3 ± 0.15 (23 cases)	5.2 ± 0.56 (16 cases)	5.8 ± 0.52 (21 cases)	2.5 ± 0.16 (16 cases)

TABLE XX. BIOCHEMICAL DATA AMONG THE WOUNDED, CLASSIFIED ACCORDING TO AMOUNT OF BLOOD LOST EXPRESSED AS PER CENT OF THE NORMAL BLOOD VOLUME
(CORRECTION "A" APPLIED)
All Values Before Operation and Anesthesia

LOSS OF BLOOD VOLUME (PER CENT)	N.P.N.	CREATININE	N.P.N. CREATININE × 10	URIC ACID	PHOSPHORUS	MAGNESIUM
0 to 5	31.0 ± 3.1 (9 cases)	1.0 ± 0.07 (9 cases)	3.1 ± 0.19 (9 cases)	4.4 ± 0.76 (6 cases)	3.2 ± 0.34 (8 cases)	1.8 ± 0.07 (8 cases)
5 to 15	36.0 ± 2.4 (9 cases)	1.1 ± 0.05 (9 cases)	3.2 ± 0.2 (9 cases)	4.8 ± 0.73 (9 cases)	3.7 ± 0.18 (9 cases)	1.9 ± 0.07 (9 cases)
15 to 25	37.0 ± 2.3 (12 cases)	1.3 ± 0.14 (12 cases)	3.0 ± 0.17 (12 cases)	3.9 ± 0.42 (9 cases)	4.0 ± 0.28 (12 cases)	1.8 ± 0.08 (11 cases)
25 to 40	38.0 ± 2.3 (19 cases)	1.7 ± 0.18 (19 cases)	2.6 ± 0.17 (19 cases)	5.0 ± 0.53 (16 cases)	4.2 ± 0.33 (17 cases)	2.1 ± 0.1 (17 cases)
Over 40	41.0 ± 2.2 (18 cases)	1.8 ± 0.13 (18 cases)	2.5 ± 0.18 (18 cases)	4.8 ± 0.60 (16 cases)	5.5 ± 0.58 (18 cases)	2.4 ± 0.18 (18 cases)

Relationship to Clinical Condition (Degree of Shock)

The interesting relationships of nonprotein nitrogen, creatinine, phosphorus, and magnesium to clinical condition are shown in Table XIX. Statistically significant rises are present for nonprotein nitrogen, phosphorus, creatinine, and magnesium as one progresses from "No Shock" to "Severe Shock," with the chief difference occurring between the moderate- and severe-shock groups, in most cases. Uric acid, at first glance, appears to rise significantly, but examination of the data fails to reveal a truly significant effect (see Table XIX, Chart 15). While a real rise might be demonstrated if more data were available, it is not shown here. As might be expected, the same positive correlation is present for nonprotein nitrogen, creatinine, phosphorus, and magnesium, as

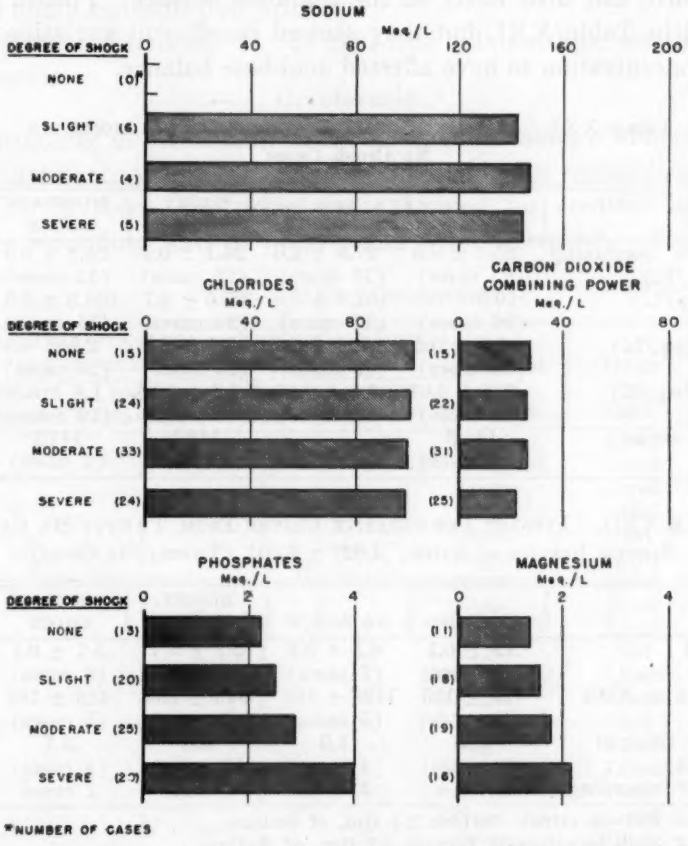


Chart 16.—Average plasma electrolytes on admission; no crush cases.

shown previously when these substances are placed against blood loss expressed in five increasing categories from 0 to 40 per cent loss and over; with this approach uric acid failed again to show a significant rise (see Table XX). As shown before, there is no correlation between passage of time and the degree of shock encountered, in that the elapsed time was the same in each of the four groups, No Shock, Slight, Moderate, and Severe Shock. This does not say that continuing hemorrhage, for example, is not related to degree of shock; certainly it is. The important factor in the development of shock is the character of the wound, especially hemorrhage, not the passage of time per se.

Information relevant to acid-base balance is shown in the Tables on Electrolytes and Urine (Tables XXI and XXII; see Chart 16). An acidosis was present in those patients with severe shock, and is reflected in the carbon dioxide combining power. A significant fall of carbon dioxide combining power can be correlated with shock. Evidence that these low values are due to a metabolic acidosis is presented in the chapter on azotemia in the Monograph mentioned in the footnote, page 672. Plasma chlorides were uniformly normal in all groups of cases; likewise, urinary chlorides, although they showed wide variations in concentration, were essentially normal. There is then no evidence of salt deprivation at this stage, that is, on hospital entry. Phosphates, although significantly higher in the severe-shock than no-shock group, in terms of total anions, could have had little effect on the acid-base balance. Plasma proteins are not included in Table XXI, but they showed insufficient variation in terms of electrolyte concentration to have affected acid-base balance.

TABLE XXI. AVERAGE PLASMA ELECTROLYTES ON ADMISSION
No Crush Cases

	ALL CASES	NO SHOCK	SLIGHT SHOCK	MODERATE SHOCK	SEVERE SHOCK
Carbon dioxide combining power (Meq./L.)	25.3 ± 0.5 (93 cases)	27.9 ± 1.0 (15 cases)	26.1 ± 0.7 (22 cases)	26.1 ± 0.9 (31 cases)	22.1 ± 0.9 (25 cases)
Chlorides (Meq./L.)	100.5 ± 0.6 (96 cases)	102.0 ± 3.0 (15 cases)	101.0 ± 0.7 (24 cases)	100.0 ± 0.5 (33 cases)	99.5 ± 0.9 (24 cases)
Phosphates (Meq./L.)	3.0 ± 0.2 (78 cases)	2.2 ± 0.3 (13 cases)	2.5 ± 0.2 (20 cases)	2.9 ± 0.3 (25 cases)	4.0 ± 0.5 (20 cases)
Magnesium (Meq./L.)	1.8 ± 0.07 (64 cases)	1.4 ± 0.05 (11 cases)	1.6 ± 0.06 (18 cases)	1.8 ± 0.10 (19 cases)	2.2 ± 0.16 (16 cases)
Sodium (blood serum) (Meq./L.)	144.3 (15 cases)	—	142.1 (6 cases)	147.1 (4 cases)	144.7 (5 cases)

TABLE XXII. AVERAGE PREOPERATIVE URINES FROM TWENTY-SIX CASES
Specific Gravity of Urine: 1.027 ± 0.001 (Twenty-Six Cases)

	ALL CASES	NO SHOCK	SLIGHT SHOCK	MODERATE SHOCK	SEVERE SHOCK
pH	5.9 ± 0.1 (26 cases)	6.3 ± 0.2 (7 cases)	5.7 ± 0.1 (6 cases)	5.7 ± 0.1 (6 cases)	5.7 ± 0.2 (7 cases)
Chlorides mg. % as NaCl	819 ± 105 (23 cases)	1128 ± 185 (5 cases)	945 ± 169 (8 cases)	423 ± 185 (5 cases)	704 ± 241 (5 cases)
Grams sodium* received since wounding	2.2 (20 cases)	1.0 (4 cases)	0.8 (5 cases)	3.7 (4 cases)	3.2 (7 cases)
No sodium since wounding	7 cases	3 cases	2 cases	2 cases	0 cases

*10 Gm. of Sodium citrate furnish 2.3 Gm. of Sodium.
10 Gm. of Soda bicarbonate furnish 2.7 Gm. of Sodium.

The blood was examined for lactic acid in five patients shortly after wounding. The findings were compared with those from tests done in normal active soldiers and in bed patients convalescing from severe wounds. The results are recorded in Table XXIIA. They show a twofold increase in the concentration of lactic acid in the wounded, when compared with normal active soldiers and with patients at bed rest.

Sodium was measured in too few cases for reliable averages. Most of the values found were within the normal range. Magnesium, like phosphates on the acid side, was increased, but not sufficiently to affect total acid-base equilibrium.

TABLE XXIIA. PLASMA LACTIC ACID CONCENTRATION IN THE WOUNDED

SOURCE	LACTIC ACID CONCENTRATION IN PLASMA (IN MILLIGRAMS PER CENT)		
	MINIMUM	MAXIMUM	AVERAGE
Normal controls (7 active soldiers)	17	24	21
Wounded examined 6 to 19 hr. after wounding (average 10 hr.) (5 cases)	29	46	38
Patients in third to fifth week of convalescence from war wounds (10 cases)	14	21	16

Urinary pH and specific gravity indicate that these men had essentially normal renal function at the time they were wounded, in that they could make both an acid and a concentrated urine.

For a further discussion of the acid-base relationship, see the section on Kidney Function.

Creatinuria

The appearance of creatine in the urine of adult males is abnormal. On the assumption that there might be some abnormality in the metabolism of creatine and creatinine in shock, the urine was examined for creatine in 32 soldiers shortly after wounding and at other times after operation. The results are

TABLE XXIIB. CREATINURIA

CASE NUMBER	SPECIMENS EXAMINED PREOPERATIVELY		SPECIMENS EXAMINED POSTOPERATIVELY		DEGREE OF SHOCK	LIVED OR DIED	COMMENT
	FOUND POSITIVE	FOUND NEGATIVE	FOUND POSITIVE	FOUND NEGATIVE			
112				1	Severe	Lived	Azotemia
A-3		1		1	Mod. sev.	Lived	
89			1		Severe	Lived	
A-4	1				None	Lived	
108		1	3		Severe	Died	"Anuria"
A-2		1		1	Slight	Lived	
109				2	None	Lived	
A-16		1			None	Lived	N.P.N. to 63
113	1		1		Slight	Lived	
120			1		Slight	Died	"Anuria"
111		1	4		Slight	Lived	
A-40			1		Slight	Lived	
126		1	1		Mod. sev.	Died	
127				1	Slight	Lived	
110			3		Severe	Lived	
131		1	2	1	Severe	Died	Oliguria
124		1			None	Lived	
118			2		Severe	Died	
130	2		1	1	Severe	Lived	Azotemia
101			3		Mod. sev.	Lived	
129	1			1	Mod. sev.	Died	Anuria
A-5	1		1		Slight	Lived	
117			1	1	Mod. sev.	Died	
A-6	1		1		Mod. sev.	Lived	N.P.N. to 60
125			1	1	Severe	Lived	Azotemia
A-1		1	1		Slight	Lived	
102			6		None	Died	
133				2	Severe	Lived	
106				2	None	Lived	
121				1	Severe	Died	
107			1		Mod. sev.	Died	
123			2		Severe	Died	Oliguria
Totals	7	9	37	16			

presented in Tables XXIIB and XXIIC. Sixty-nine urine specimens were tested (see Table XXIID). Creatine was found in the urines of 22 of the 32 patients (Tables XXIIC and XXIID). Nearly one-half the cases (6 out of 15) showed creatine in the urine when examined preoperatively, while 20 of 28 patients whose urines were examined postoperatively were positive for creatine.

TABLE XXIIC. ANALYSIS OF RESULTS IN THIRTY-TWO PATIENTS TESTED FOR CREATINURIA

CLASSIFICATION	DEGREE OF SHOCK		RELATION TO OPERATION*				
	NONE TO SLIGHT (NUMBER OF CASES)	MODERATE TO SEVERE (NUMBER OF CASES)	PREOPERATIVE (NUMBER OF CASES)	POSTOPERATIVE (NUMBER OF CASES)	BOTH (NUMBER OF CASES)	LIVED (NUMBER OF CASES)	DIED (NUMBER OF CASES)
Patients who had both positive and negative urinalyses (9 cases)	2	7	Pos.: 2 Neg.: 5	Pos.: 8 Neg.: 5		4	5
Patients who had only negative urinalysis (10 cases)	6	4	2	6	2	9	1
Patients who had only positive urinalysis (13 cases)	6	7	1	9	3	8	5
Total 32 cases							

*Four cases had a negative as well as a positive postoperative value and are therefore counted twice here. Two cases had no preoperative determination. Only one case was negative postoperatively and positive preoperatively.

TABLE XXIID. SUMMARY OF SIXTY-NINE URINE SPECIMENS WHICH WERE TESTED FOR CREATININE

SOURCE	POSITIVE (44 SPECIMENS)	NEGATIVE (25 SPECIMENS)
Preoperative	7	9
Postoperative	37	16
From patients who were in none or slight degrees of shock	18	11
From patients in moderate or severe shock	26	14
From patients who died subsequently	20	7
From patients who lived subsequently	24	18

TABLE XXIII. VAN DEN BERGH AND PLASMA HEMOGLOBIN LEVELS IN PATIENTS WITH VARIOUS KINDS OF WOUNDS

TYPE OF WOUND	VAN DEN BERGH (MG. % OF BILIRUBIN)	PLASMA HEMOGLOBIN (MG. %)
Liver	0.36 ± 0.04 (9 cases)	10.7 ± 1.4 (10 cases)
Kidney	0.42 ± 0.07 (8 cases)	12.8 ± 2.3 (8 cases)
Intraabdominal	0.43 ± 0.11 (15 cases)	10.1 ± 1.8 (15 cases)
Thoracoabdominal	0.39± 0.04 (7 cases)	12.7 ± 2.2 (7 cases)
Thoracic	0.58 ± 0.07 (15 cases)	10.1 ± 1.6 (15 cases)
Soft parts *with* fracture	0.57 ± 0.05 (36 cases)	10.9 ± 1.1 (42 cases)
Soft parts *without* fracture	0.49 ± 0.12 (6 cases)	11.3 ± 2.9 (10 cases)

Creatinuria was present at some time in all but one of the patients who died and in whom the tests were made (Table XXIIC). It was present in approximately one-half the patients who lived. Table XXIIC suggests that creatinuria is more likely to occur in the group of patients who had been in severe shock than in the others. Of the 18 patients who had been in moderately severe to severe shock, only 4 failed to show creatinuria. It appears that creatinuria may be the result of metabolic changes which accompany shock.

Van den Bergh and Plasma Hemoglobin Levels

Type of Wound.—On comparison of the type of wound with bilirubin and plasma hemoglobin, no impressive relationships are found (see Table XXIII).

The Passage of Time.—The van den Bergh index rises significantly with increasing time from wounding to examination (see Table XXIV). This may be due to the absorption of breakdown products from hematomas, and to impaired liver function (see the following section on Liver Function in the Newly Wounded Man). The situation is simpler here (since these patients have in most cases not yet been transfused with blood) than it is later when large volumes of blood have been given. These may tend to elevate the bilirubin level. The plasma hemoglobin level appears to rise with the passage of time, but this is not significant, as far as the data at hand are concerned.

TABLE XXIV. VAN DEN BERGH AND PLASMA HEMOGLOBIN LEVELS COMPARED WITH THE PASSAGE OF TIME

HOURS FROM WOUNDING UNTIL BLOOD SAMPLE DRAWN	VAN DEN BERGH (MG. % OF BILIRUBIN)	PLASMA HEMOGLOBIN (MG. %)
1 to 6	0.45 ± 0.05	11.4 ± 0.9
	(47 cases)	(48 cases)
7 to 12	0.64 ± 0.07	9.4 ± 1.4
	(23 cases)	(27 cases)
13 to 24	0.69 ± 0.07	11.1 ± 2.1
	(13 cases)	(18 cases)

Clinical Condition (Degree of Shock).—There is no clear relationship of shock to bilirubin or to plasma hemoglobin levels (Table XXV). However, when the bilirubin level is placed against the blood loss (Correction "A") a significant relationship seems to emerge, although the values are all at a rather low level (Table XXVI). Presumably the rise is to be accounted for by hemolysis

TABLE XXV. VAN DEN BERGH AND PLASMA HEMOGLOBIN LEVELS COMPARED WITH DEGREE OF SHOCK

All Values Before Operation and Anesthesia, Excluding Crush Cases

DEGREE OF SHOCK	VAN DEN BERGH (MG. % OF BILIRUBIN)	PLASMA HEMOGLOBIN (MG. %)
None	0.43 ± 0.08	12.1 ± 1.8
	(11 cases)	(14 cases)
Slight	0.68 ± 0.10	11.3 ± 1.6
	(23 cases)	(23 cases)
Moderate	0.54 ± 0.06	10.8 ± 1.4
	(27 cases)	(33 cases)
Severe	0.47 ± 0.05	8.8 ± 0.9
	(21 cases)	(24 cases)

of blood in damaged tissues, followed by absorption into the blood stream. There is no apparent correlation of blood loss with plasma hemoglobin values.

Blood Sugar

The blood sugar level* in the 56 wounded men we studied as they arrived at the forward hospital is above normal (Table XXVII and Chart 17). Some of the men had had plasma, but more had had a significant quantity of blood in resuscitation before the determination was made.

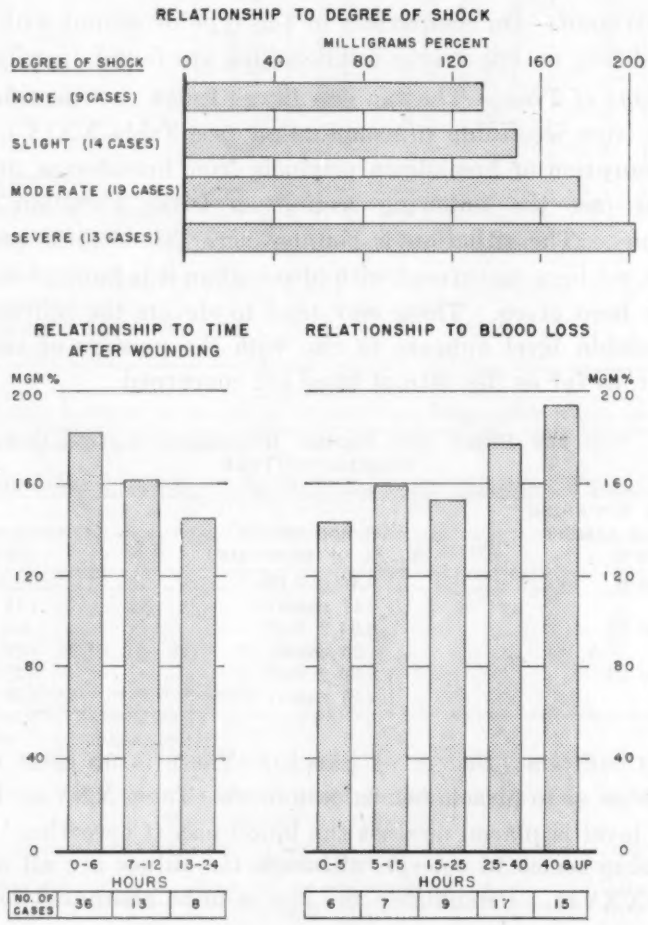


Chart 17.—Plasma glucose levels.

The blood sugar level appears to rise significantly both with increase in blood loss and with increase in severity of shock. The glucose level may fall with the passage of time following wounding, but our data are not extensive enough to demonstrate this. Presumably the elevation in blood sugar level is due to mobilization of liver glycogen following adrenal activity and probably reflects the emotional and physical stress the individual has experienced.

*Normal by the method we used is 80 to 90 mg. per cent.

TABLE XXVI. BILIRUBIN AND PLASMA HEMOGLOBIN COMPARED WITH BLOOD LOSS
Three Cases With Slight Blood Volume Gain Considered to Have 0 Per Cent Blood Loss; Crush Cases Excluded

BLOOD LOSS* CORRECTION "A"	0-5%	5-15%	15-25%	25-40%	OVER 40%
Bilirubin (mg. %)	0.31 ± 0.07 (6 cases)	0.56 ± 0.10 (8 cases)	0.50 ± 0.10 (10 cases)	0.52 ± 0.05 (20 cases)	0.64 ± 0.11 (18 cases)
Plasma hemoglobin (mg. %)	15.5 ± 2.6 (7 cases)	11.2 ± 3.6 (8 cases)	9.8 ± 2.0 (11 cases)	14.3 ± 1.6 (20 cases)	10.0 ± 1.2 (18 cases)

*Observed values less all fluid received until blood volume determination was completed.

LIVER FUNCTION IN THE NEWLY WOUNDED MAN

As described in the section of the monograph mentioned in the footnote, page 672, on "Liver Function in the Severely Wounded," the only direct laboratory test of liver function carried out here was bromsulfalein excretion. The van den Bergh index and uric acid levels have also been considered as being in part at least related to liver function.

Bromsulfalein Retention

On Arrival at the Most Forward Hospital.—In 59 patients the bromsulfalein retention on arrival was 12.4 ± 1.2 per cent, forty-five minutes after 5 mg. per kilogram body weight had been injected. This is well above the normal of 1.0 ± 0.1 per cent (see the Monograph, 45 subjects) and above our arbitrarily chosen upper limit of normal of 3 per cent.

Location of Wound.—In 22 patients with extremity wounds there was 13.3 ± 2.3 per cent retention, and in 18 with abdominal wounds there was 14.7 ± 2.1 per cent retention—no difference. However, 11 men with penetrating chest wounds had only 7.0 ± 1.8 per cent retention, significantly lower than found in the other groups.

Relationship to Time Following Wounding.—There was no difference in the bromsulfalein retention in men examined within the first six hours after wounding, 14.4 ± 1.8 per cent (29 patients), or after the first six hours, 13.1 ± 1.6 per cent (19 patients).

Relationship to Shock.—In 55 patients separated into the four groups, No Shock, Slight, Moderate, and Severe Shock, no significant correlation with the bromsulfalein excretion could be found; neither was there any correlation with blood volume or hemoglobin loss.

TABLE XXVII. PLASMA GLUCOSE LEVELS (MG. PER CENT)

	NONE	SLIGHT	MODERATE	SEVERE	
Relationship to degree of shock	134 ± 9 (9 cases)	149 ± 9 (14 cases)	178 ± 13 (19 cases)	202 ± 26 (13 cases)	
	0 TO 6 HR.	7 TO 12 HR.	13 TO 24 HR.		
Relationship to time after wounding	182 ± 13 (36 cases)	161 ± 10 (13 cases)	144 ± 7 (8 cases)		
	0 TO 5%	5 TO 15%	15 TO 25%	25 TO 40%	40% & UP
Relationship to blood loss (correction "A")	143 ± 12 (6 cases)	159 ± 15 (7 cases)	153 ± 7 (9 cases)	177 ± 18 (17 cases)	194 ± 23 (15 cases)

Relationship to Plasma Administration.—Curiously enough, there was a great increase in bromsulfalein retention (14.0 ± 2.0 per cent, 25 patients) in men who had had one or two units of plasma over those who had had none (8.0 ± 2.0 per cent, 15 patients). Three or more plasma units did not increase the effect beyond that produced by one or two units. The effect was transient and disappeared between the first and second day following operation.

Van den Bergh and Uric Acid

Van den Bergh and uric acid have been discussed elsewhere in this same section.

SUMMARY

In the past, battle wounds have been described chiefly in terms of organic damage or tissue loss. The purpose of this section is to describe, shortly after the soldier has arrived at the forward hospital, the latent consequences of his wounds, as they have influenced organic function and produced abnormalities of the blood volume and chemistry, and abnormalities in the urine. These matters were studied before resuscitative efforts had yet been made, in 108 patients. Altogether, 186 patients were studied in the course of the work carried out by the Board for the Study of the Severely Wounded.

In considering patients who had received not more than one unit of plasma, or none at all, it was observed that the hematocrit was higher in those with abdominal wounds than it was when the wounds were in the periphery of the body; but even in the case of abdominal wounds, the average hematocrits were somewhat below normal. While severe hemoconcentration can occur in burns, in crush cases, and in abdominal wounds, this was infrequent in our cases and is by no means a general characteristic of shock as we saw it.

When the group of patients who had received little or no plasma or blood therapy at the time of first examination was divided into two parts, depending upon whether or not more or less than 30 per cent of the blood volume had been lost, a puzzling situation was apparent: the plasma protein concentration in the more severely bled-out group was 6.1 Gm. per cent. This is 6.1 per cent below normal. On the other hand, the hematocrit in this same group had fallen to 36 from the normal of 47, a reduction of 23.4 per cent. The hematocrit thus fell about four times as much as the plasma proteins. One implication of this is that the blood had been diluted with protein-rich fluid. Its possible source is discussed.

Evidence is presented that the plasma protein level was not influenced by the plasma therapy, although the hematocrit was. There is a sharp fall in hematocrit as one passes from the no-shock to the severe-shock groups. Other examples of the independent variation of these two factors are given.

Men can lose about 75 per cent of their blood volume (corrected) and a corresponding quantity of hemoglobin and yet recover, more than previously generally supposed. The blood loss with various types of wounds is discussed. Data are given to show that there is a quantitative relationship between blood

volume loss or hemoglobin loss and the degree of shock met clinically. This supports the view that the major cause of the shock we encountered is hemorrhage.

No important differences in blood volume or hemoglobin loss were encountered with the passage of time from wounding to examination. This is possibly to be accounted for by the high priority and consequent rapid evacuation given to bleeding wounds.

The clinical condition of the newly wounded man offers abundant evidence that his internal state has been profoundly altered by the time he enters the forward hospital. In addition to the matters already mentioned, this has been studied in terms of nitrogenous waste products, electrolytes, bilirubin, and blood sugar. In general, these were not found to be influenced by the location of the wound. The nonprotein nitrogen blood level rises rather strikingly with delay following wounding. The full significance of this is not clear, but it offers grounds for some interesting speculation. As one examines the four shock groups in sequence from no shock to severe shock, significant rises in nonprotein nitrogen, creatinine, phosphorus, and magnesium are found.

Acidosis was present in the patients with severe shock. There is a considerable fall in carbon dioxide combining power here as compared with that present in the no-shock group of patients. The acidosis appears to be of the "metabolic" type.

No evidence of salt deprivation was found on hospital entry. Examination of the admission urine specimen with regard to hydrogen ion concentration and specific gravity indicates that the men studied had essentially normal renal function at the time they were wounded.

The van den Bergh index rises significantly with increasing time from wounding to examination. This is discussed briefly. No clear relationship of shock to bilirubin or plasma hemoglobin levels was found. The blood sugar level was found to be above normal. It is particularly high in the severe-shock group.

Definite depression of liver function, as measured by bromsulfalein retention, was found on hospital arrival. This is discussed in its relationship to location of wound, to time following wounding, and to shock. The administration of one or two units of plasma appeared to impair liver function still further. This is a transitory effect and is not increased by giving three or four units of plasma.

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Review of Recent Meetings

TWENTY-SEVENTH MEETING OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

ST. LOUIS, MO., MAY 28-30, 1947

FREDERICK C. FISHBACK, M.D., WASHINGTON, D. C.

Dorsal Sympathetic Ganglionectomy for Intractable Asthma, Duane Carr, Memphis.—Asthma, a syndrome of unknown origin, lacks a clear-cut physiologic pathology. The normal power to expand and contract is lost, and the bronchi remain constantly in contraction. The asthmatic state is probably a combination of swollen bronchial mucous membranes and an inability to cope with thick, viscid secretions; that it is due to bronchospasm is incorrect. Vagal stimulation does not produce asthma. Contraction of the bronchi persists between attacks. The bronchi may be more sensitive to adrenalin after denervation. Earlier workers had obtained varying degrees of relief by alcohol injections of the dorsal ganglia, by excision of the posterior pulmonary plexus, and by combination of dorsal ganglionectomy with excision of the pulmonary plexus. Surgery is restricted to asthmatic patients of long standing who are irresponsive to the usual drugs (namely, epinephrine or aminophyllin) and allergic procedures. **Dr. Carr** reported the end results of five cases in which operation was done, three to ten years previously. The first two cases were by the Adson technique with excision of the third and fourth ganglia; the other three were performed through a periscapular incision, with removal of short segments of the third and fourth ribs, and extrapleural excision of the second, third, and fourth ganglia. Three of the patients were colored and two were white; all exhibited long periods of previous disability. Some were immediately relieved; in some, relief was delayed, and one was worse immediately after operation, with later improvement. The severity and frequency of attacks have been markedly reduced so that they are controlled with aspirin or tetral. The patients are all able to work.

Dr. A. J. Grace described eleven cases in which he had excised the posterior pulmonary plexus, with three cures, and varying degrees of benefit to the others. He emphasized the need for eradicating infection and eliminating allergies. Paravertebral block had not been effective in his hands. Surgical division of the vagal branches should reduce spasm and secretion, and benefit the accompanying emphysema. **Dr. Osler Abbott** also advocated the transpleural resection of the vagal components, and noted that there were five fairly regular branches. Expiratory function is improved and vital capacity increases. Emphysema is benefited. He transplants the vagal stump into the pleura to discourage regeneration. **Dr. Ralph Adams** wondered whether any of these patients developed Raynaud's diseases in the hands. He observed that since these were postganglionic operations, it was reasonable to expect that the benefit would be delayed. He reported four cases of emphysema and cysts, in which two of the operations were of the vagal type, and two were dorsal ganglionectomies. **Dr. J. H. Chandler** (the co-author) said that no instances of Raynaud's disease had occurred, that the operation had no effect on bronchial inflammation or infection, and that they carefully avoided the stellate ganglion. **Dr. Carr** said that the recommended extrapleural procedure was designed to minimize shock in the debilitated patient.

Experiences With a New Method for the Control of Intrathoracic Aneurysms, Osler Abbott, Atlanta.—Although many methods have been used to obliterate aneurysms within the thorax, there has been continued search for a more satisfactory method. The goal has been the chronic progressive fibrous obliteration of the sac. Pearse has demonstrated the gradual occlusion of the dog's aorta with cellophane. Conflicting reports have resulted from the use of different types of cellophane. Moisture-resistant cellophane is nonirritating and causes

no reaction. Polythene cellophane, on the other hand, causes a marked fibrous reaction and has been used in the treatment of aneurysms of the thoracic aorta, its branches, and of the pulmonary artery. The group which was reported included fourteen syphilitic aneurysms, two dissecting aneurysms, two congenital aneurysms, and one of the pulmonary artery (Eisenmenger complex). The use of x-rays was urged, particularly the lateral projection, and angiocardiography for diagnosis. Seventy-five per cent of the aneurysms showed no pulsation. Many of the aneurysms were multiple. Congenital aneurysms simulated the embryonic aorta. Contact of the aneurysm with any bony structure is a contraindication to operation. Should the aneurysm compress the bronchus as evidence by atelectasis or apparent contact of aneurysm and bronchus, the chest should be decompressed prior to intubation by removal of a segment of clavicle, or excision of the upper two ribs unilaterally with the contiguous portion of the sternum or the resection of a V-shaped wedge from the upper sternal margin. Preliminary decompression is usually indicated in aneurysms of the ascending aorta and innominate artery. The cellophane is applied loosely and fixed with sutures to prevent displacement. Even partial encirclement of the aneurysm with cellophane may produce relief. Polythene cellophane should not be applied to the auricle because it is too irritating. **Dr. Karl Poppe** reported his experience with twelve thoracic aneurysms of which only two were operable. Old age and cardiac decompensation are contraindications to operation. His best results were in fusiform aneurysms of the descending aorta. After operation, the aneurysm does not decrease in size roentgenologically.

Arteriovenous Fistula of the Lung, Herbert C. Maier, New York.—Arteriovenous fistula of the lung is in reality a cavernous hemangioma with an aneurysmal communication between the pulmonary artery and pulmonary vein, producing an inadequacy of oxygenation. Rarely the bronchial artery may communicate with the pulmonary vein. These fistulas are not of traumatic origin. They are frequently associated with telangiectasia about the face, especially the lips. A loud murmur is usually heard over the portion of the lung containing the fistula; this murmur is louder during inspiration. These patients present a picture of cyanosis, dyspnea, clubbing of the fingers and toes, and polycythemia with headache. The heart is not enlarged. Roentgenograms show a fluctuating tumor and the contours of the involved vessels. Angiocardiography proves the case, conclusively. The red blood cell count may be as high as 11,000,000; the hemoglobin may be 24 Gm. per cent; the hematocrit may be up to 80 per cent, and the arterial oxygen saturation down to 70 per cent. Arteriovenous fistulas of the lung should be distinguished from true polycythemia and congestive heart lesions. Malignant hemangioma of the lung is very rare and does not present the symptomatology of arteriovenous fistula. Treatment consists of excision of the fistulous communication, preferably by segmental resection. In practice, usually lobectomy or pneumonectomy is needed to eradicate the shunt. Adequate vascular channels must be preserved for the return of venous blood to the heart. Pneumothorax is wholly ineffective since it does not collapse the vessels involved.

	ARTERIOVENOUS ANEURYMS	
	SYSTEMIC CIRCULATION	PULMONARY CIRCULATION
Blood volume	Increased	Increased
Plasma volume	Increased	Normal
Hematocrit	Normal	Increased
Oxygen saturation	Normal	Decreased
Cardiac output	Increased	Normal
Enlargement of heart	Present	None

In the discussion, **Dr. R. H. Sweet** reported two such cases in which the lesion was located in the right middle lobe. (This was similar to the case reported by **Dr. John C. Jones** at the Chicago meeting in 1944.) **Dr. L. M. Shefts** emphasized the familial character of these fistulas and said that phlebothrombosis should not be an uncommon complication because of the increase in blood viscosity. **Dr. R. H. Byron** said that disappearance of the polycythemia and cyanosis may be delayed after operation. **Dr. Dewey Bisgard** said that these arteriovenous fistulas had undoubtedly been missed in the past. **Dr. E. I. Evans,** in speaking of the increased blood volume, wondered what became of the red blood cells and surmised that perhaps more blood was lost at operation than suspected. He pointed

out that thrombosis was due to stasis and reduced cardiac output. In closing, **Dr. Maier** said that absence of cyanosis indicated that the bronchial artery participated in the shunt rather than the pulmonary artery.

Resection of a Coarctation of the Aorta Followed by Subclavian-Aortic Anastomosis, James F. O'Neill, Winston-Salem.—Of those individuals with coarctation, 75 per cent die before they are 40 years old. Death may occur suddenly, often in unrecognized cases, due to rupture, or cardiac insufficiency and subsequent decompensation, and/or infection. Crafoord's two original cases done in 1944 were described, both patients surviving, and Gross' experience was related, beginning in 1945, with fifteen cases and but two deaths. Blalock's experiments were noted (1943) in which, using anesthetized dogs, the arch of the aorta was divided, the proximal end closed, and the subclavian artery anastomosed to the distal aortic segment. Twenty-five per cent of the dogs survived. Excision of the coarcted area and end-to-end anastomosis is the better procedure except when the extent of the excised segment is sufficiently great to cause tension on the suture lines. In this situation, the subclavian artery, which is usually dilated, may be employed, instead of the short proximal aortic limb, in the anastomosis. Clagett first carried out this maneuver in August, 1946, when confronted with too great tension on the suture line of a proposed aortic end-to-end anastomosis. On Dec. 21, 1946, Bradshaw performed the same operation in a patient presenting the characteristic symptoms of high blood pressure in the arms, low blood pressure in the legs, cold feet, weakness, distended cervical veins, and systolic and diastolic murmurs over the pulmonic area. The approach was through the bed of the fifth rib on the left side. **Dr. H. Bradshaw** displayed a clamp which he had devised for occluding the aorta and subclavian artery. Surgery is possible in coarctation because the lesion itself is responsible for the development of numerous collaterals; in fact, the subclavian artery is frequently found to be dilated so that it is as large as the aorta. In the discussion, **Dr. S. W. Harrington** (speaking for Dr. O. T. Clagett) said that the operation was one of necessity rather than of choice. Dr. Clagett has done five cases, employing the subclavian artery to restore aortic continuity; four of these were end-to-end, and one was an end-to-side anastomosis. In the latter operation, the blood pressure in the arms did not decrease postoperatively. In this series, one patient died during his hospital stay. Dr. J. W. Gale suggested that should the subclavian artery be smaller than the aorta, the subclavian be transected obliquely to afford a matching lumen. **Dr. H. T. Barkley** reported a patient who died forty-eight hours after operation with an intact anastomosis where the occluding clamps had fractured the intima and caused a thrombus to form. **Dr. L. R. Davidson** emphasized the need of turning up sufficient cuff before making the anastomosis. All of the speakers used an everting, continuous mattress suture, following Gross' suggestion and practice, in contrast to Crafoord who employed a continuous over-and-over suture.

Aortic-pulmonary Anastomosis for Pulmonary Stenosis, Willis J. Potts, Chicago.—The indications for an aortic-pulmonary anastomosis are the same as those for the Blalock operation, namely, the tetralogy of Fallot. The rationale of both operations is based on need to augment the pulmonary blood flow which is reduced by the pulmonary stenosis. The incision is through the fourth interspace. By the use of a very ingenious clamp, which partially occludes the aorta permitting the flow of blood beyond the clamp, a side-to-side anastomosis is made with the pulmonary artery. The anastomotic hiatus is from ¼ inch to 5/16 inch in length. The procedure has been carried out in twenty-seven patients. There were twenty-five survivors and of these twenty-four were much improved, and only one slightly improved. **Dr. J. J. Hanlon** said only one aortic-pulmonary anastomosis had been done at Johns Hopkins.

Diseases of the Esophagus, Paul H. Holinger, Chicago.—This presentation consisted of an excellent colored moving picture taken through an esophagoscope, demonstrating many interesting conditions of the esophagus.

Surgical Management of Carcinoma of the Lower Two-thirds of the Esophagus and Cardiac End of the Stomach, John W. Strieder, Boston.—The chief factor in the improve-

ment of esophageal cancer surgery has been the adaptation of the stomach, replacing the excised esophageal segment, within the chest. Continuity is re-established by anastomosis of the mobilized stomach to the remaining esophagus. In effecting anastomoses in high-lying cancers, the esophageal stump is brought over and anterior to the arch of the aorta. This technically difficult procedure carries with it an operative mortality three to five times as great as when the esophagus is left in place. From the standpoint of surgical anatomy, he urged that the esophageal tube be divided into fourths rather than the usual thirds. Exploration was done in sixty-seven cases and forty-four were operable. In age, the patients ranged from 52 to 84 years, but the general condition of the patient was more important than the chronologic age. All cases are biopsied preoperatively, and bronchoscopy is carried out as well as esophagoscopy, to exclude invasion of the bronchial tree. Transfusions and intravenous alimentation are employed to improve the patient's condition. Forty-eight hours before operation, penicillin is started (50,000 units every three hours). Anesthesia is begun with endotracheal nitrous oxide to permit the use of the high-frequency current, thereby saving time in opening the chest. Once the chest is opened, the nitrous oxide is replaced with pentothal, ether, and oxygen. Exposure is obtained by excising the ninth rib. The anastomosis of the stomach and esophagus is done in three layers. Of the forty-four patients found to be operable, 65 per cent survived operation. There was one interesting case in which a second resection was done for recurrence two months after the original operation, and the patient is now apparently in good health. Gastric dilatation occurred only when both vagi were cut at operation and was combated by continuous suction drainage. In the discussion, **Dr. Richard Sweet** said that he was opposed to inversion and purse-stringing the esophageal end of the stomach, since it precluded a secure, neat closure. Reporting an extensive experience at the Massachusetts General Hospital, he said that 69 per cent of the tumors of the lower esophagus were resectable in contrast to 64 per cent for the middle third of the esophagus. The mortality rate was 12 per cent for the lower third and 22 per cent for tumors of the middle third of the esophagus. He advocated excision even when it was obvious that it was only a palliative measure. It was most encouraging to learn that the mortality rate for the cases done in 1945 and 1946 was only 9 per cent. **Dr. M. E. DeBakey** and **Dr. W. E. Adams** described methods of enlarging the esophageal hiatus at the site of the anastomosis. **Dr. Adams** stated that the recent mortality at the University of Chicago was but 17 per cent. His longest survivor has thus far lived fifty months. He suggested that in closing the chest, two Foley catheters be employed since their inflatable bulbs permit drainage without plugging. **Dr. Adams** said that he had one patient living and well nine years after operation. In his last twenty-seven cases, there had been only two deaths. In his experience, high resection and anastomosis were no more dangerous than in the lower third of the esophagus.

Congenital Esophageal Atresia and Tracheo-Esophageal Fistula, Clayton G. Lyon, San Francisco (read by Brodie Stephens because of author's illness).—Approximately 468 cases of esophageal atresia, with or without tracheal fistula, have been reported. Forty-eight patients have been successfully operated upon. This anomaly has been classified by Ladd into five types, of which types III and IV are much the most common. These types consist of a blind upper esophageal stump and the distal esophagus communicating either with the wall of the trachea or its bifurcation at the carina. About 85 per cent can be corrected surgically; in the remaining 15 per cent, the esophageal ends are too widely separated to permit re-establishment of esophageal continuity. The presence of frothy oral secretion and persistent regurgitation indicates esophageal atresia. Under the fluoroscope, 1.0 to 0.5 c.c. of lipiodol may be instilled through a small catheter to determine the level of the upper esophageal segment. The lipiodol is then aspirated. Barium should never be used. When a flat plate of the abdomen shows gas in the gastrointestinal tract, it confirms the presence of a tracheo-esophageal fistula (type III, IV, or V) and indicates probable operability. The earliest surgical attack on this problem was cervical esophagostomy and gastrostomy, with subsequent construction of an antethoracic esophagus. In 1939, the first successful intrathoracic esophago-esophagostomy was performed through a right-sided extrapleural approach.

The use of endotracheal anesthesia was advocated, which would reduce respiratory motion and permit frequent aspiration, plus a transpleural approach on the left side to facilitate the mobilization of the stomach and its anastomosis with the proximal esophageal pouch. Four cases were reported, done within the last six months; two patients had died within twenty-four hours and thirty-six hours, respectively, of aspiration; a third died thirty days after operation, due to a second and unrecognized stricture below the site of the anastomosis. The fourth was doing well four months after operation. Two rows of sutures were employed in the anastomosis. In the discussion, **Dr. Cameron Haight** described his right-sided extrapleural approach, and emphasized that the presence of air in the stomach was reasonable evidence of operability. **Dr. N. L. Leven** reported a series of forty-two cases; ten patients are living with gastrostomy and cervical esophagostomy, and eleven are living after primary anastomosis.

Esophageal Hiatus Hernias of the Short Esophagus Type: Etiologic and Therapeutic Considerations, A. M. Olsen, Rochester, Minn.—One hundred seventy-five patients with esophageal hiatal hernias of the short esophagus type have been seen at the Mayo Clinic during the last ten years, comprising 10 per cent of all hiatus hernias. The larger group of hiatal hernias are of the sliding and para-esophageal type and must be distinguished from those of the short esophagus type. X-ray examination and endoscopy are necessary to make the diagnosis. The esophagus is less than fourteen inches long. The patients give a history of dysphagia, substernal pain, and hemorrhage. They occur most commonly in patients between 50 and 70 years of age, and the duration of symptoms is usually over four years. There may be an associated scleroderma. Esophagoscopy reveals inflammation, ulceration, and an incompetent cardiac sphincter. Gastric mucosa is obtained on biopsy. It is suggested that many of these are acquired rather than congenital in origin, namely, they occur late in life and the patients frequently give a history of long-standing digestive disturbances, with vomiting and regurgitation, which produce inflammation (esophagitis) and ulceration. Many hernias of this type have an associated stricture of the esophageal-gastric junction, the result of a primarily incompetent hiatus which has permitted the backflow of gastric juice, producing inflammation and later stricture and stenosis. As a rule, surgery is not indicated for this type of hernia. When stricture is present, dilation should be carried out, up to 50 French. The ancillary measures consist of an ulcer (high protein) diet, antacids, weight reduction, and sleeping with the head of the bed elevated. **Dr. Stuart Harrington** emphasized the importance of distinguishing these short esophageal hernias from true hernias; the latter are treated by replacement and repair of the defect, while the former are treated by elevating the diaphragm 3 to 5 cm., and reconstructing it at that level, above the cardia. They are prone to recur. A hernia of the short esophagus type may coexist with a para-esophageal hernia. **Dr. Richard Sweet** stated that in ninety-one esophageal resections for carcinoma, 13 per cent had hiatal hernias of the short esophagus type with characteristic symptoms. **Dr. Cameron Haight** and **Dr. W. E. Adams** urged the use of esophagogastrostomy in the surgical treatment of this condition. The frequency of the association of the short esophagus with carcinoma of the esophagus was commented upon.

Controlled Respiration in Transpleural Operations, Frederick R. Mautz, Cleveland.—The physiologic aspects of the mechanical control of breathing were reviewed, laying particular emphasis on the integration of open pneumothorax and anesthesia. As long as the respiratory center remains alert, the alveolar carbon dioxide will be fairly constant. Interference with the elimination of carbon dioxide gives one more concern than the oxygen intake. One may compensate for hypoxia by increasing the available oxygen in the anesthetic mixture. Inertia of the respiratory center will permit excessive accumulation of carbon dioxide. The position of the patient on the operating table reduces vital capacity. The open pneumothorax of thoracotomy reduces vital capacity as much as 50 per cent. On opening the chest, there is an increased respiratory effort to compensate for diminished aeration which often becomes progressively worse. Open pneumothorax impairs carbon dioxide excretion. Reflexes from the wound, the lungs, or the trachea may either stimulate or depress the respiratory center. In 1940, **Dr. Mautz** demonstrated an ingenious apparatus for intermittent pulmonary

ventilation, consisting of a respirator built into the circuit of a gas machine. The rebreathing bag is contained in a rigid glass cylinder, permitting the anesthetist to visualize and anticipate the patient's ventilation requirements. Although the patient is apneic, ventilation is adequate. Nitrous oxide and ether are administered endotracheally. No positive pressure is used until the pleura is opened, and then never more than 10 to 15 mm., and at a rate about one-half of normal. A short period of hyperventilation produces apnea which blocks out stimulation of the respiratory center and permits the anesthetist to assume control of respiration. **Dr. Claude Beck** said that manual compression of the gas bag was neither dependable nor satisfactory since prolonged manual compression was not conducive to the return of normal function. He considered a mechanical respirator, such as Dr. Mautz described, as essential and emphasized the need of adequate ventilation before attempting resuscitation of the heart. **Dr. Frederick Kergin** said that when prolonged anoxia occurred during intrathoracic operations, the contralateral lung might become atelectatic due to mediastinal shift. **Dr. Mautz** urged again that it was not only necessary to combat anoxia with an adequate oxygen supply, but even more important to eliminate carbon dioxide.

The Diagnosis and Operability of Bronchogenic Carcinoma, John H. Gibbon, Philadelphia.—The over-all survival rate for both bronchogenic and gastric cancer after surgical extirpation is 22 per cent. Further improvement in the treatment of bronchogenic cancer depends upon earlier diagnosis and more radical surgery. The earliest symptoms were cough, bouts of pneumonitis, and chest pain; other symptoms of value were sputum, hemoptysis, weight loss, dyspnea, and wheeze. Fifty-six patients with proved cancer of the lung were seen in the past fourteen months. Exploration was done in thirty-one of these and twenty-one were resectable, with but two hospital deaths. Cytologic examination of bronchoscopically removed secretion has proved a valuable aid in early diagnosis. A recent improvement in this technique, applicable to secretion-free patients, consists in instilling salt solution into the suspected bronchus and then aspirating it. In twelve of the patients in whom no biopsy was obtained, malignant cells were found in the secretion, and nine of these were explored, largely on the basis of finding neoplastic cells in the bronchial secretion. Contraindications to surgery are the presence of a hemothorax and metastases outside the involved hemithorax. Paralysis of the diaphragm should not be regarded as a contraindication, nor should a recurrent laryngeal nerve palsy, since 10 per cent of these latter occur without satisfactory explanation. He urged a more radical extirpation, often opening the pericardium to ligate the pulmonary veins. This is desirable since the neoplasm frequently extends along these vessels. The pulmonary artery is ligated extrapericardially. In this series, the tissue resected included portions of the diaphragm in two cases, the phrenic nerve in two, the chest wall in one instance, and the vagus nerve in one. **Dr. Peter Herbut,** the coauthor, described a larger series of patients (284) from whom 362 specimens were obtained. Eighty-nine of the 284 had proved cancer of the lung. Malignant cells were found in the bronchial secretion of 77 of the 89 patients (86 per cent), while positive biopsies were obtained in 40 patients (45 per cent). He described the Papanicolaou technique. The neoplastic cells are pleomorphic and fall into three categories, namely, (1) squamous cell (75 per cent), (2) undifferentiated (4 per cent), and (3) all others (21 per cent), each with well-defined cellular characteristics. Wider application of this valuable method of early diagnosis should result in a higher rate of resectability. In the discussion, **Dr. Michael DeBakey** said that biopsy confirmed the diagnosis before operation in two-thirds of his cases. In a series of 412 cases, 121 patients were considered inoperable, and 291 were thought operable; 45 of these refused operation and in 246 exploration was done; of this latter group, 99 were found to be inoperable (40 per cent). Of those explored, 60 per cent were resectable. The mortality rate prior to 1942 was 46 per cent; since then it has been 19 per cent. The five-year survival rate has been 23 per cent (better than that of gastric cancer). He noted that most patients die within the two-year period, of recurrence and extension. On the basis of this large experience, 2 survive five years out of every 25 patients; however, if all 25 were resectable, then 5½ might be expected to survive.

Cancer of the Lung. Relationship of Topographic Features to the Interval and Late Results of Operation, Arthur H. Aufses, New York.—In 1934 and 1941, papers were presented by Dr. Harold Neuhof, reviewing large series of lung tumors from the standpoint of topographical classification. This classification is broken down into three groups: (1) Bronchus tumors (invasive lesions derived from the main bronchi), which are topographically diffuse. They possess marked tendencies to spread in the submucosa and via the lymphatics. (2) Circumscribed tumors (as identified topographically by x-ray view) where lymphatic involvement is limited or late. In this category, lobectomy is often effective. (3) Peripherally invasive (medial aspect more or less circumscribed but invasive of adjacent structures such as pleura, pericardium, or diaphragm). This type often arises from branch bronchi and spreads via the lymphatics. This series comprises fifty-four patients, subjected to pneumonectomy or lobectomy, who survived operation. The follow-up includes a higher percentage of circumscribed tumors (amounting to 25 per cent of all pulmonary carcinomas) because a larger proportion of patients were operable and survived for longer periods. The microscopic features of these tumors bear no significant relationship to the period of survivial. Adenocarcinomas were found slightly more frequently in the circumscribed group. In Group 1 (diffuse tumors) there were 7 survivors out of 23 cases, of more than two years' duration (30.4 per cent); in Group 2 (circumscribed tumors) there were 8 survivors out of 18 cases (44.4 per cent); and in Group 3 (peripherally invasive tumors), there were 13 cases with 2, surviving over two years (23 per cent). The patients with hilar node involvement usually died within one year; this was particularly true of main bronchus tumors. Lobectomy is ineffective when there is lymph node involvement, but has a place in the treatment of circumscribed tumors. Twenty-eight per cent of the patients in whom lobectomy was performed survived the two-year period; 37 per cent of those in whom pneumonectomy was done survived longer than two years. If patients remain well for two years, it is probable that they are cured. The absence of any correlation between the microscopic picture and the survival period was again emphasized.

Carcinoma of the Lung, Ralph Adams, Boston.—Out of a series of 182 cases of cancer of the lung, resection was done in 56 patients, with 8 hospital deaths. Six deaths occurred in the first 17 resections (35 per cent), while there were only 2 deaths in the last 39 (5 per cent). In the surviving 48 patients, certain studies were carried out. No patient with undifferentiated (oat cell) carcinoma has lived two years following resection. Of 15 patients living and well longer than one year, 13 were epidermoid in type. Three patients with epidermoid carcinoma grade III (Broder's classification) have lived over two years and one over five years. Lymph node involvement definitely worsens the prognosis. In the 48 patients, 35 had pneumonectomy with 14 (40 per cent) surviving more than two years, including 2 who are living and well after five years; 13 had lobectomy with 6 (46 per cent) surviving more than two years and with 2 living and well more than five years. Only in epidermoid carcinoma did the study reveal that the longer the duration of symptoms prior to resection, the shorter the expected period of survival. In other types, the survival period was more closely related to cell type than to any other factor. If the patient survives the first two years after resection, he has a 60 per cent chance of cure.

In discussing the previous three papers, **Dr. Evarts Graham** said that any statistics based on less than five-year survivals were fallacious. One should not be encouraged by any figures based on a two-year period because cancer is most likely to recur within that period and some patients might live that long, anyway, without operation. Were the operative mortality the only consideration, lobectomy or partial resection might be the treatment of choice. In cancer of the breast, some patients have recovered with local excision or simple mastectomy, but the best over-all results come from the radical operation. With gland involvement, pneumonectomy should be done. It is frequently impossible to determine the presence or absence of involved glands by inspection alone. They are less likely to be present when the tumor is distant from the hilum. Pneumonectomy, rather than partial lung resection, has produced more five-year survivals. **Dr. John Strieder** stated that smears of aspirated bronchial secretions in cancer of the lung had proved 85 per cent positive. **Dr. Jerome Head** emphasized the high degree of disability after pneumonectomy

in patients over 60 years of age. He said that partial lung resection should be given consideration in these cases since preservation of pulmonary function is important. The disability attendant upon pneumonectomy should be considered rather than the operative mortality. He praised the high degree of accuracy in diagnosis which obtained in the microscopic examination of bronchial secretions. **Dr. Avery** reported a series of 50 resected lung cancers: 29 were of the hilar or main bronchus type with 4 patients living; 14 were of the circumscribed type with 5 patients living, and 17 were of the peripherally invasive type with no extended survivals. He reiterated that there was no apparent correlation between cell type and survival period because the degree of malignancy depends upon the "worst" rather than typical cell. **Dr. John Gibbon** urged pneumonectomy as the treatment of choice, but said that there must be surety of diagnosis before any lung is removed. **Dr. Peter Herbut** said that in the last 60 cases of microscopic secretion examination, only 3 had been missed. Regarding false positives, there had been none in the last year. More recent experience would have excluded the two earlier false positives. The cells found in lung abscess, exhibiting metaplasia, can now be distinguished from cancer cells. Tuberculosis presents a distinctive pattern and picture. **Dr. Harold Neuhof** again drew attention to the sharp differences between survival rate at two years and five years. He did not agree that regional lymph node involvement in cancer of the lung should be contrasted with nodal involvement in cancer of the breast. He urged prompt surgical treatment once the diagnosis is made, since slow growing, circumscribed tumors may metastasize or invade at any time.

The Treatment of Inoperable Bronchogenic Carcinoma by Methyl-bis, Edward F. Skinner, Memphis.—Investigations of some 300 nitrogen mustard compounds during the war revealed that they had a specific toxic effect on rapidly growing cells, such as cells of the bone marrow and cancer cells. Since 1942, nitrogen mustard compounds have been used in the treatment of Hodgkin's disease and lymphomas in 126 hospitals. Methyl-bis, a nitrogen mustard compound,* is supplied by Memorial Hospital, New York, N. Y., for use under certain conditions of control and study. The hazard of the appeal of treating cancer by "shots" instead of by surgery, where it is indicated, is obvious. There are admittedly a few long-standing survivors after tremendous doses of x-ray for bronchogenic carcinoma, but this is contrary to the general experience. Forty patients with bronchogenic carcinoma have been treated but this report covers seventeen treated during the preceding year. These cases were unsuitable for surgery because of distant metastases. Some of these patients have shown improvement which could not be derived from any other treatment at our disposal, including x-ray therapy. The benefits last for several weeks to several months. The greatest improvement occurs after the first treatment; subsequent treatments are progressively less effective until finally they are of no help at all. There were no toxic manifestations, aside from nausea and vomiting and anorexia for the first twenty-four hours after treatment, which were at least partly eliminated by the injection of 100 mg. of pyridoxine at the time of therapy. The tumors remain stationary for variable periods of time, as corroborated by x-ray views, and then later resume growth. In some cases methyl-bis was given at the same time as x-ray therapy but without improvement in results. It is possible that the doses of methyl-bis were inadequate, but doses twice as large as the standard dose produced no better results. There was a greater gain in weight on methyl-bis alone, than when x-ray was used as an adjunct. It is desirable to give as large a dose as the patient will tolerate. Clinically, the results are better than x-ray therapy; in addition, it is cheaper and can be given in the office. It is conceded that the results in lymphoma are better than those in bronchogenic carcinoma. Methyl-bis comes in 10 mg. vials, which are diluted with 10 c.c. of normal saline solution. The dose is 0.1 mg. per kilogram of body weight given intravenously in split doses over five consecutive days or five days apart. Ten cubic centimeters of normal saline solution are given immediately after the methyl-bis injection. As an office procedure, methyl-bis is given once a week. It can also be administered during a saline infusion by injection through the tubing.

*Manufactured by Merck & Co., Inc., Manufacturing Chemists, Rahway, N. J.

In the discussion, **Dr. Michael DeBakey** reminded us that the same apparent clinical improvement in inoperable cancer cases may be obtained by a similar, increased interest, improved morale, and better care of such cases. **Dr. Fred Harper** told of ten patients with inoperable carcinoma who had been treated with methyl-bis: three had died, showing some necrosis of the liver. Seven were still living, two with obvious metastases; in one, the metastases had disappeared; one patient had coughed up plugs of tumor tissue. Methyl-bis seemed to reduce cough and pain. **Dr. Avery** said that methyl-bis had been used at the Hines Veterans Hospital in nine cases of pulmonary cancer; six patients seemed benefited as evidenced by the need for fewer hypodermics. In one instance, a superior vena cava obstruction had disappeared, while undergoing treatment. **Dr. Osler Abbott** said that he had used methyl-bis in five patients but that without the psychotherapeutic influence gained by having the patient know something new was being tried on him, he had observed no benefit.

Nonmalignant Lesions of the Lung Simulating Bronchogenic Carcinoma; Report of Thirty Cases, Lyman A. Brewer, III, Los Angeles.—During the past six years, 300 patients with bronchogenic carcinoma have been seen but only 45 per cent yielded a positive biopsy at bronchoscopy. In the remainder, diagnosis was made by clinical means, often exploratory thoracotomy. Since only a small ratio of these patients (53) were operable, the desired goal has been earlier and earlier diagnosis. This led to exploration in many patients without a proved diagnosis of pulmonary cancer. Thirty patients were operated upon for suspected malignancy, in whom the lesion was beyond the range of bronchoscopic vision; 27 had resections of some type, and 1, who refused resection, later had a thoracoplasty. All 30 cases presented benign lesions which fell into three groups. The inflammatory group consisted of pulmonary abscess, nonspecific granuloma, tuberculosis, and echinococcus disease. The benign tumors were adenoma, lipoma, and fibroma. The congenital conditions included lung cysts and an intrathoracic thyroid. Bronchogenic carcinoma occurs five times more frequently in males than females; in these benign lesions, the incidence is the same in both sexes. The x-ray picture may reveal a central or peripheral mass, an atelectatic lobe, a cyst, or abscess. Most of these patients could have been cured only by pulmonary resection. Such experience should encourage the surgeon to resect peripheral pulmonary lesions in which bronchogenic carcinoma is suspected. If carcinoma is found, resection offers the only chance of cure; if the lesion is nonmalignant, this study demonstrates that in most instances the pathologic condition is one that can be cured by resection.

In discussing this paper, **Dr. Evarts Graham** urged that exploratory thoracotomy be done oftener. All tuberculomas should be resected since they may become active and produce a bilateral spread. **Dr. David Waterman** said that a sputum, positive for tuberculosis, may mask a carcinoma and that it was unwise to put too much weight on a single sputum examination, even though positive. **Dr. Frederick Mautz** reported a case of gumma of the lung, which is exceedingly rare, in which the Wassermann test was not reported until after operation. **Dr. Edgar Davis** said that all solitary spherical intrapulmonary lesions should be explored even if one is unable to make a clinical diagnosis. In 40 such cases, he has performed 39 operations and found 70 per cent of them to be malignant. Twelve of these patients were without symptoms, yet 8 of them had malignancies. Many cysts are malignant. **Dr. Richard Sweet** also urged frequent exploratory thoracotomy but said that, even after exploration, diagnosis was not easy. He advised doing biopsies at the time of exploration. Chronic pneumonitis may be very difficult to distinguish from bronchogenic carcinoma. **Dr. Lincoln Brown** said that lipoid pneumonia was progressive and should be resected. **Dr. Brewer** counseled more explorations and segmental resections.

Specialism in Surgery, I. A. Bigger, Richmond, Va. (Presidential Address).—Specialism in medicine dates back to antiquity. References to specialism are found in accounts of ancient Greek and Egyptian medicine. Specialism seems to have disappeared in the Middle Ages possibly because of the academic and philosophical aspects of medicine as it was taught at that time. In the nineteenth century, the development of new instruments and techniques afforded a rational basis for the beginnings of specialties as known today. Ophthalmology

appeared first, in 1851, followed by urology in 1871. Other specialties developed slowly until the 1890's. Bevan, twenty-five years ago, asserted that one-third of all physicians professed to be specialists. The delimitations of specialties are changing. In 1937, Rankin said that the general surgeon of today lives in the afternoon of his career. Halsted advocated the training of a well-rounded general surgeon. Barker pointed out that specialism was the logical consequence of the division of labor, and that it should increase the productivity and fruits of labor. It was feared that specialism would lead to lower standards, less intellectual ruggedness, and a narrow outlook with loss of the over-all picture. A broad training in basic science designed to cultivate breadth of vision must be the foundation for training in any specialty, if the broad perspective and wise understanding shall persist. The ideal concept envisions an organization where consultation, conference, and cooperation between those trained in various specialties is routine, carried on hand-in-hand with fundamental research. The present specialty boards indicate certain trends. The prescribed periods of training are perhaps too rigidly fixed. It might be well to allow credit for work done in other fields, to refute the criticism of regimentation and narrowness in such prescribed training. It is well to remember that when any type of training becomes established by custom, it may assume legal stature.

Pulmonary Edema: Experimental Observations on Dogs Following Acute Peripheral Blood Loss, Robert M. Eaton, Grand Rapids (Rose Lampert Graff Prize Essay).—These exceedingly important and fundamental experiments were the result of the author's interest in the effects of blood loss and were carried out while he was in charge of the St. Louis Blood Bank during the war. Acute peripheral blood loss alone will produce changes in the lungs consisting of edema, hemorrhage, vascular congestion, and endothelial damage, which in turn cause a block to normal circulation. Because of the stasis in the pulmonary circuit, an acute systemic circulatory imbalance ensues in which arterial pressures are low and venous pressures high. The lung changes following peripheral blood loss are not transient and may last five days. Dogs were bled 25 per cent of their estimated normal blood volume and certain observations were made. Using the photographic Wigger's manometer and the kymograph, simultaneous direct pressure readings were obtained from the femoral artery, the femoral vein, and the pulmonary artery. After the induction of hemorrhage, all pressures dropped, but this was followed by a temporary pressure elevation in the venous system (femoral vein and pulmonary artery) without any rise in pressure in the peripheral arterial system. These findings were probably due to stasis and increased back pressure in the pulmonary circuit. Employing a technique of lung desiccation, a predictable pattern of pulmonary moisture change was noted. It was elevated during the first 20 minutes, became subnormal at 45 minutes, was above normal at 1¼ hours, and then leveled off to normal 4 hours after the blood loss. Using the same technique, pulmonary edema was found to be aggravated by the infusion of normal saline solution, but not by the administration of blood or plasma. During the first three hours after hemorrhage, plasma protein levels were low and hematocrit readings high. Another interesting observation was that as a result of blood loss, there was an immediate increase in pulmonary lymph flow as judged by cannulization of the pulmonary lymphatic (right thoracic) duct. Microscopic sections were made which gave corroboratory histologic evidence of alveolar and tissue edema and hemorrhage. The initial hemorrhage causes an anoxia which damages the alveolar capillary endothelium resulting in an increased permeability to fluids, which in turn produces the edema, congestion, and interstitial hemorrhage. Rapid deep breathing augments the negative intrathoracic pressure and increases the already present pulmonary edema and hemorrhage as the great veins of the thorax become overdistended. In combating the effects of a massive peripheral hemorrhage, anoxia should be overcome by giving whole blood, never saline solution, and the administration of oxygen under pressure so that it may penetrate the film of water, coating the alveoli.

The Effect of Pulmonary Inflation and Deflation Upon the Maintenance of Circulation, Samual Alcott Thompson, New York.—Active inflation and deflation of the lungs causes a compression and dilatation of the pulmonary capillaries, which sets up an artificial circula-

tion in the normal direction over the entire body, without benefit of any heart activity. Such movement was demonstrated in dogs, immediately after death by the use of radioactive sodium, fluorescein, and oxygen. Dogs were anesthetized with intraperitoneal nembutal, and 2 to 5 c.c. of heparin were injected. Ten minutes later, the endotracheal tube was clamped for twenty or thirty minutes; on releasing the clamp, a resuscitator was started and the tracer substances injected. After radioactive sodium was injected into a femoral artery or vein, its presence could be demonstrated in a brief interval, by use of a Geiger counter, in specimens obtained from the carotid artery or the femoral artery of the other leg. Using fluorescein (2 c.c. of 5 per cent solution), which emits a golden-green glow when exposed to ultraviolet light, its presence could be easily seen in the skin, mucous membranes, the coronaries, and brain. Blood samples for the determination of oxygen saturation were taken from the femoral artery at the beginning of the experiment, again shortly after clamping the endotracheal tube, and forty-five to sixty minutes after resuscitation had been carried on. The only possible source of oxygen was the pulmonary capillaries as they filled and emptied with alternating inflation and deflation of the lungs. Within ten minutes of asphyxia, by the use of resuscitation, the oxygen saturation of the blood in the femoral artery regains the pre-asphyxial level. Unless clotting is prevented by the use of heparin, there can be no circulation. Heparin prolongs the time available for resuscitation. Without resuscitation, there can be no forward motion of the blood. It was shown that blood circulates over the entire body although not in life-sustaining quantity or rate. However, this circulation might protect the heart and lungs during a given period of resuscitation. Alternating positive inflation and suction deflation are 100 per cent more efficient than either inflation or deflation alone. The pumping action is the result of the compression and dilatation of the pulmonary capillaries.

The Regeneration of Defects of the Trachea and Bronchi. An Experimental Study, Rollin A. Daniel, Jr., Nashville.—In 1940, Cappel showed that a tracheal defect could be repaired with fascia which was later transformed to collagenous fibrous tissue. Since fascia is not rigid, it is unsuitable for bridging a defect in continuity. Dogs were employed, and the experimental procedures were carried out under intravenous nembutal anesthesia. Full-thickness segments of the trachea were excised, including from two to four cartilage rings. The defects were bridged by flanged tubes (8 to 10 mm. in diameter) of vitallium, steel, or glass, which were tied into the divided ends of the trachea with encircling braided silk ligatures. The mediastinal pleura was closed over the repair. The animals were sacrificed at intervals from two weeks to a year. They tolerated the presence of the tubes well. The beginning regeneration of cartilaginous rings is evident at two weeks, and, with time, the regenerated rings very closely resemble those which were removed. The new connective tissue cells differentiate into cartilage cells. The lining epithelium also regenerates slowly, and resembles scar epithelium, being composed of a thin layer of small cells which appear to be stratified. There is no regeneration of cilia or goblet cells. **Dr. Stuart Harrington** described a similar technique for the repair of tracheal defects, however, using plastic tubes.

An Improved Method of Resection of Pulmonary Segments. Report of a Technique Used in Over Sixty Cases of Bronchiectasis, F. M. Woods, Boston.—Pulmonary diseases amenable to resection often involve segments of lobes as well as entire lobes. It is desirable to preserve the normal segments of lobes as functioning units. When the disease is extensive, involving multiple areas, the conservation of all healthy segments is essential for optimum function. This method, based on the individual ligation technique, applies this procedure to artery, vein, and bronchus of the pulmonary segment. It facilitates the visualization of the segmental planes of cleavage, permitting the separation of diseased and healthy segments without damage to the latter. In bronchiectasis particularly, this conservation of healthy lung tissue has broadened the scope of resective surgery to include many more patients with extensive bilateral disease than were feasible when lobes were regarded as surgical units. Although segmental resection does not replace lobectomy, it has proved a valuable adjunct, especially for the patient with multilobar disease. In the past thirty months, seventy segmental resections have been performed; fifty for bronchiectasis and twenty for other conditions, which include cysts, tuberculomas, and benign tumors. In seven patients, multiple

bilateral resections have been carried out, usually the basal segment and lingular segment on the left, and the basal segment with middle lobectomy on the right. The technique of the operation was shown in an excellent movie, and its great value lies in the preservation of functioning lung tissue in an otherwise badly diseased lung. **Dr. Herbert Adams** pointed out that Dr. E. D. Churchill had initiated segmental resections in 1937. In seventy-three segmental resections, there had been six bronchial fistulas (all in lingulectomies) but they had all healed spontaneously. **Dr. David Waterman** emphasized the importance of conserving good lung tissue, in spite of occasional leaks from raw surfaces and atelectasis in the remaining lobar segment. Atelectasis of the remaining portion of a lobe, especially of a lower lobe, can be avoided if the remnant is kept in its proper position by suture. It is important to ligate segmental bronchi high up, so that there is no stump or only a very short stump. This method is prone to leave exposed raw lung surfaces and every effort should be made to cover them with pleura.

The Place of Exploratory Thoracotomy in the Management of Intrathoracic Disease, John B. Grow, Denver.—This study shows that there should be no hesitancy in advocating exploratory thoracotomy for all obscure intrathoracic lesions. It is a safe procedure with low morbidity, and in this series of cases there were no deaths. One must adopt an attitude of readiness to explore the chest when the usual diagnostic procedures fail, as is so frequently the case with upper lobe lesions beyond the reach of the bronchoscope. Of 200 lesions which were explored, 21 per cent proved to be malignant. In this series, there were 113 intrapulmonary lesions, of which 29 (25.6 per cent) were malignant. There were 86 cases in which the lesion was described as "circumscribed," and 20 (23 per cent) of these were malignant. The remaining cases of this group consisted of 37 instances of tuberculosis (24 were tuberculomas), 13 lung cysts, 3 coccidioidal granulomas, 3 diaphragmatic hernias, 2 liver abscesses, 1 echinococcus cyst, and 1 arteriovenous aneurysm. Forty-four operations were performed for cancer of the lung; only 45 per cent of these had been diagnosed by bronchoscopic biopsy. A high percentage of chronic abscesses of the upper lobes are due to intrabronchial neoplasms which should be treated by exploration and resection, instead of the common practice of drainage. Diagnostic radiation therapy should be abandoned in favor of obtaining tissue for pathologic diagnosis before instituting any type of therapy. The effect of x-ray therapy on tumors of the lymphoma group is not uniform since not infrequently Hodgkin's disease proves radioresistant. Exploratory thoracotomy is without risk; all deaths in this series were the consequence of the surgical treatment of the underlying condition. There were five deaths after pneumonectomy and one after lobectomy. Exploration in 35 patients with suppurative disease (chronic abscess) revealed 11 (31 per cent) with bronchogenic carcinoma.

Chronic Nonspecific Suppurative Pneumonitis, W. E. Adams, Chicago.—The etiology is not known. Its onset is insidious and it runs a very chronic course. The duration of symptoms in the ten patients reported here ranged from six months to twenty-two years; the duration in the majority of the cases was from two to ten years. All the patients were over 30 years old. There is usually a productive cough with episodes of hemoptysis accompanied by low-grade toxicity, as evidenced by fever. There may be some pain. X-ray examination reveals an ill-defined opacity extending out from the hilar region without cavity formation. The condition may be located in any part of the lung, and at times is bilateral. It must be distinguished from pulmonary tuberculosis, bronchogenic carcinoma, nontuberculous lung abscess, and bronchiectasis. The pathologic picture is one of chronic, diffuse inflammation, showing marked fibrosis, which is responsible for narrowing of the bronchial lumen and atelectasis. Other features are thickening of the alveolar walls. Lymphoid hyperplasia, lymphocytic and plasma cell infiltration, and the presence of fat-filled macrophages in the alveolar spaces. Clubbing of the fingers does not occur. In short, the condition is characterized by its insidious onset, chronic course, and pulmonary inflammation without abscess formation or bronchial dilatation. Of the ten cases, five were treated by lobectomy, two by pneumonectomy, two by drainage; in one bilateral case, only biopsy was done. **Dr. Robert Janes** pointed out the similarity of this condition to chronic lipoid pneumonia in which the lung shows marked fibrosis and a high fat content. **Dr. Ralph Bettman** told of a case of nonspecific suppurative

pneumonitis, which presented the picture of lung tumor, but responded to x-ray therapy. In closing, **Dr. Adams** said that x-ray therapy might be effective if given early in the disease. Although he employs chemotherapy in these cases, he urged that resection be done because of the difficulty in differentiation from carcinoma. Lobectomy is usually sufficient.

Pulmonary Resection for Chronic Abscess of the Lung, Donald L. Paulson, Dallas.—In 1941, the co-author, **Dr. Robert Shaw,** had advocated a one-stage drainage operation for lung abscess, as soon as the diagnosis was made. In view of the fact that chronic lung abscesses are often multiple, involving more than one lobe, and may be productive of marked fibrosis throughout a lobe or lobes, the likelihood of any drainage operation curing such a condition is very small. A series of 86 patients was presented, 50 of whom had had resection for chronic lung abscess with a reduction in mortality to 5 per cent in contrast to a 15.2 per cent mortality in 1941. The rate of cure has risen from 57.6 per cent in 1941 to 80 per cent in the present series. Drainage operations should be reserved for acute abscesses, used as an expediency in the very ill patient, and also to reduce the size of large abscess cavities in the hope of conserving functioning lung tissue. Resections were done in abscesses of long duration (two to eighteen months) and when the abscesses were multiple. Resections were complicated by postoperative empyemas in 28 per cent of the cases. Surgical drainage and pulmonary resection for chronic lung abscess should be regarded as complementary in the treatment of this condition.

Pulmonary Resection for Chronic Lung Abscess, Edward M. Kent, Pittsburgh.—This report is an analysis of thirty consecutive cases of chronic lung abscess treated by pulmonary resection. Males outnumbered females in a ratio of five to one. Ages ranged from 17 to 64 years with an average of 33 years. The duration of the lesions varied from 4 to 42 months, with an average duration of 15.8 months. The cases were divided into three groups. Group I consisted of eleven cases of multiple abscesses involving all the lobes of a lung; these patients were treated by pneumonectomy. There was one death on the ninth postoperative day from a diffuse pneumonitis in the remaining lung; there were no postoperative empyemas and only one transient bronchial fistula. In Group II, there were eight cases of multiple abscesses confined to a single lobe. Seven of these patients were treated by lobectomy without a complicating empyema or bronchial fistula. The eighth one died on the operating table of asphyxia resulting from a severe hemorrhage in the involved lung before the affected lobe could be mobilized. Group III consisted of eleven cases of solitary abscess confined to a single lobe and the patients were treated by lobectomy. There were no deaths in this group; a single bronchial fistula occurred which was followed by an empyema. Seven patients in the entire group had been subjected to previous drainage without improvement; five were in the multiple abscess groups (I and II) and two were in the solitary abscess group. The operative mortality was 6.7 per cent. The low incidence of postoperative empyema (one case, 3.3 per cent) was the result of the application of the individual ligation technique which minimizes bronchial fistulas, and of the use of penicillin before, during, and after operation. In the acute solitary abscess, surgical drainage still has a role, but in the chronic, multilocular, multilobed abscess, drainage is wholly unsatisfactory because of the high mortality, long morbidity, tendency to recur, and frequency of residuals.

In discussing these two papers, **Dr. J. D. Moody** emphasized the need of preventing the spread of infection from the diseased bronchus and showed an ingenious apparatus for plugging the bronchus, consisting of a balloon with an umbrella-like anchor, which produced atelectasis distal to the balloon. **Dr. Duane Carr,** commenting on the difficult problem of excessive bronchial secretions, said that he placed the patient in the prone position. He used an ironing board supported on two blocks, at either end, with elliptical cutouts for the head and operative side of the chest. **Dr. Robert Shaw** gave the improvements in anesthesia their just due for the increased safety in lung resections in suppurative disease. Bronchial stumps should be trimmed very short because long bronchial stumps invite postoperative empyemas. **Dr. A. R. Curreri** advised the use of Trendelenburg's position to control excessive secretions. **Dr. E. J. Grace** praised the effects of the use of aerosol when combined with wetting agents

in reducing secretion before operation. He spoke of the synergism of penicillin and streptomycin but urged that large amounts be employed. As a wetting agent or detergent, he used 3 c.c. of zephiran (1 to 1,000 solution). **Dr. J. K. Poppe** observed that it was often difficult to differentiate chronic abscesses from bronchiectasis. Operations on patients with poorly draining abscesses carried a risk twice as high as those for bronchiectasis. The better epithelialized the abscess cavity, the lower the risk. **Dr. O. C. Brantigan** said he used the face-down position, and utilized the cerebellar headrest and shoulder braces. **Dr. Donald Paulson** said that because of the individual ligation technique, there had been no contralateral spread and only one ipsilateral spread, and this probably a direct extension to a middle lobe after an upper lobectomy. **Dr. Kent** emphasized the value of the prone position and the importance of an immediate available bronchoscope during these resections to open a plugged bronchus and prevent asphyxia.

The Effect of Chemotherapeutic Agents on the Growing Tubercle, Robert G. Bloch, Chicago.—It is known that streptomycin inhibits the in vitro growth of the tubercle bacillus. However, because of the absence of blood supply, streptomycin does not penetrate the centers of necrotic areas. The effect of various chemotherapeutic agents were investigated (1) by the influence of such agents on the tubercle bacillus growing in culture, employing the culture technique of Dubos and Davis (1946). The tubercle bacillus is grown in a liquid medium, which produces an active, subsurface, diffuse submerged growth, which three days after inoculation can be read on the colorimeter. One cubic centimeter of streptomycin completely inhibits the growth of 0.4 micrograms of the culture. The addition of ferric ammonium citrate does not enhance the effectiveness of the penicillin. It has been shown histologically that iron does not enter the tubercle. (2) Investigations regarding the influence of streptomycin on normal tissues (namely, in rabbits): streptomycin when injected intradermally irritates the skins of animals producing sometimes necrosis but chiefly a nonspecific inflammation with abundant immigration of eosinophiles, followed by induration and fibrosis. The skin irritations caused by streptomycin alone appear more severe than those caused by tuberculous infection but microscopic examination proves them to be very superficial, causing much less tissue destruction than in streptomycin-treated or untreated tuberculous areas. It has been observed clinically that aerosol streptomycin inhalations cause marked irritation of the bronchial mucosa. This observation was confirmed by exposing rabbits to aerosol streptomycin inhalations over various periods of time. The aerosol globule, which is 2.5 microns in diameter, is ideal for penetrating the lungs. (3) The development of tuberculous lesions was not influenced by streptomycin when treatment was begun as early as four days after inoculation with the bacillus. Streptomycin was given intradermally to rabbits in doses of 0.1 to 0.5 mg. at the time of inoculation and four and eight days afterward. The skin-irritating effect of streptomycin was again noted. Caseation was inhibited only when the streptomycin injections were begun immediately after inoculation. A bovine strain was used routinely, but in a few instances when lesions were produced by human strains, the inhibitory effect of streptomycin was considerably greater and was effective even when treatment was not begun immediately after inoculation. Examination of sections for acid-fast bacilli showed considerable reduction in the numbers of organisms in caseous and noncaseous infected areas where treatment had been coincidental with inoculation. There was no appreciable reduction in the numbers of bacilli found where the administration of streptomycin was begun four days or longer after inoculation. Radioactive phosphorus has a special affinity for the caseating tubercle; when injected into an organ or tissue, the phosphorus will penetrate the tuberculous area.

Closed Intrapleural Pneumonolysis. An Analysis of 1000 Consecutive Operations, J. Claude Day, Detroit.—This report covered 1,000 consecutive operations done in the last seven years at the Herman Kiefer Hospital and the Wm. H. Maybury Sanitarium. While intrapleural pneumonolysis has enhanced the effectiveness of pneumothorax, certain undesirable complications are attendant upon its universal use. It should not be regarded as an innocuous procedure to be employed routinely whenever restraining adhesions, no matter how complex, are present. The over-all mortality rate was 18 per cent. The complications were

the development of persisting effusions (199), empyemas (50), and the obliteration of the pleural space (63). Sixty-five cases were abandoned because of extension of the disease or ineffectiveness of the pneumothorax. Complications were more frequent when pneumonolysis could not be completed, and when the cavity was apparently increasing in size. Late complications were more numerous than early ones. The results in 432 cases were described as effective. There were 5 deaths at the time of operation and 161 later deaths, of which 110 could be ascribed to complications. The operation should be restricted to unilateral tuberculosis where the amount of parenchymal damage indicates the need for prolonged collapse. Intrapleural pneumonolysis should not be performed in the presence of tuberculous empyema, acute pleurisy with effusion, or extensive parenchymal tuberculosis; nor should it be done when there is pleural symphysis or adhesions arising from the periphery of thin-walled cavities.

In the discussion, **Dr. Edward Wells** said that these deaths were not due to pneumonolysis but to the underlying disease. There should be no mortality from the operation alone. Many of the patients would have died but for the pneumonolysis which rendered a pneumothorax effective. **Dr. Julian Moore** questioned the validity of the reasoning by which the over-all 18 per cent mortality rate was arrived at; he pointed out that 18 per cent was the approximate mortality rate of all late cases of tuberculosis. He felt that the actual mortality rate that could be directly ascribed to pneumolysis was about 1.5 per cent. **Dr. Louis Davidson** stated that there was a wider field of vision obtained when using the two-cannula thoracoscope than with the single cannula type, such as Dr. Day had employed. The two-cannula thoracoscope permits disinsertion of weblike adhesions from the parietal pleura. In a series of 192 ineffective pneumothoraces, satisfactory collapse had been achieved in 75 per cent by intrapleural pneumonolysis, with only 8.4 per cent of complicating empyemas. The incidence of empyema as a complication of pneumothorax (10 to 20 per cent) is greater than in pneumonolysis. **Dr. E. J. O'Brien** urged the importance of evaluating the late, rather than the early, results of pneumonolysis. He felt certain that ultimate results in this type of patient would be better if more thoracoplasties were done and fewer pneumonolyses. **Dr. Day** said that the aim of pneumonolysis was the conversion of an incomplete collapse to an effective one and he hoped that by the observation of certain indications, patients on whom pneumonolysis was performed should enjoy the same outcome as those on whom pneumothorax alone was done.

Preliminary Anterior Chondrocostectomy Combined With Closed Cavity Drainage and Posterior Thoracoplasty, Edward S. Welles, Saranac Lake.—The conventional thoracoplasty brings about complete closure and conversion of sputum in the more common, moderate-sized tuberculous cavities. However, in the so-called giant cavities, although thoracoplasty may greatly reduce the cavities in size, they usually persist as small triangular or slitlike remnants. Removal of the anterior rib segments may bring about further reduction in size without complete closure. Revision operations which are difficult and dangerous have not appreciably altered the results. It was hoped that the combination of the Monaldi cavity drainage (1936) with thoracoplasty might produce the desired results. To avoid the risk of serious wound infection which might arise from the sinus tract of the drainage tube, it was deemed wise first to do an anterior chondrocostectomy. The size of the giant cavity was distinctly diminished after the anterior operation. This was then followed by a conventional first stage posterior thoracoplasty. Such surprising collapse of the cavity occurred that it was decided to postpone drainage once more and do the second posterior stage. In the first six cases, complete closure of the cavity resulted. The next case proved a failure, and the resulting change in size and shape of the cavity made later drainage hazardous and impossible. Since then a number of cases have been done, pursuant to the original plan, namely, the drainage tube is inserted about two or three weeks following the anterior stage. Suction is then started and the posterior stages performed one month later. To date, there has been complete cavity closure in all cases. In some the tubes have been removed and the cavities have remained closed; others are still on suction. It is difficult to determine accurately how long the drainage tube should remain in place. Perhaps when the drainage is scant and no evidence of cavity can be seen by x-ray examination and the patient is free of sputum, the tube might be removed. This combination of operations affords a more effective method of closing giant cavities than any previous technique.

Book Reviews

Human Torulosis: A Clinical, Pathological and Microbiological Study With a Report of Thirteen Cases. By L. B. Cox, M.D. (Melbourne), M.R.C.P. (Edinburgh), F.R.A.C.P., and J. C. Tolhurst, M.Sc. (Melbourne). Pp. 149, with 67 illustrations. Melbourne, 1946, Melbourne University Press.

Torulosis, also known as cryptococcis, is an infection due to a yeast which has a tendency to invade the central nervous system. In their classical monograph, *Torula Infection in Man*, Stoddard and Cutler in 1916 designated the etiologic agent as *Torula histolytica*. The present monograph is a scholarly presentation of the subject by two Australians, one a neurologist and the other a bacteriologist. Although the disease has been considered to be relatively rare, one of the authors has encountered eleven cases since 1936 in southern Australia. Their purpose in this work is to present thirteen unrecorded cases of human torulosis with meticulous clinical and pathologic descriptions, and to define the characteristics of the causative organism with the results of animal inoculation. In addition, they have brought the literature on the subject together. Without any doubt, this represents the definitive statement on the subject. It is not unlikely that many cases of torulosis are being overlooked, and this volume may serve as a stimulus for clinicians to consider the possibility of torulosis in any ill-defined case of encephalomeningitis with and without pulmonary manifestations.

One of the intriguing features of torulosis as emphasized by the authors is a generalized enlargement of the lymph nodes which present evidence of Hodgkin's disease. They believe that this association is more than coincidental and on page 62 state, "We believe that chronic torulosis may result in glandular enlargement, and occasionally in true Hodgkin's disease." And elsewhere, on page 126, "Hodgkin's disease which occasionally complicates torulosis is a separate disease initiated from the infection." In this connection, it is of interest that American workers have recently implicated Brucella as a cause of Hodgkin's disease. Apparently experimental torulosis in lower animals is not associated with the granulomatous lesion of Hodgkin's disease.

While the monograph reflects the postwar shortage of high grade paper, the 67 illustrations are excellent reproductions. The index is very comprehensive, and this with the bibliography should be of considerable aid to students of the disease.

Tentative Operatoires Dans le Traitement de Certaines Psychoses. By Egas Moniz, Professor de Neurologia, Lisbonne, Masson & Cie.

This book was published in 1936 after twenty patients had been treated by injection of alcohol into the central white substance of the prefrontal lobe or by cutting the same white matter with an instrument which Moniz calls a cerebral leucotome. This leucotome is inserted into the white matter, then a central wire core is pushed into the trocar so that a loop projects near the distal end and by rotating the instrument spheres of white matter 1 cm. in diameter are separated. These injections and spherical leucotomies of the original operations have since been modified by others and have become known as prefrontal lobotomy.

The book consists essentially of three parts:

The first part is a discussion of the considerations which led to the introduction of these operations. It consists of a discussion of cerebral localization, the function of the frontal lobe, and a consideration of normal and abnormal emotional reactions.

It is concluded that the emotional life is a summation of the physiologic activity of the nerve elements of the brain in which the frontal lobes have an especially important role.

Extensive nerve cell centers and their connections by rapidly forming new and successive composition or functioning circuits are the anatomic physiologic basis of the normal emotional life. In the normal person, these combinations rapidly change, but if these connections become more or less fixed, the patient suffers from depression, hypochondriasis, ideas of grandeur or persecution, or develops an anxiety state.

The destruction of parts of the central white substance in the frontal lobe was instituted to destroy or break up these fixed pathways in the emotionally disturbed patient.

The second part of the book consists of a very detailed report of each of the twenty patients on whom operation had been done.

The third part of the book is a discussion of the technique and results of operations. The modifications made in the technique as experience was acquired are described and discussed. An attempt is made to correlate the location and extent of the destructive lesion with the result obtained. It is even suggested that the fibers affected in hypochondriasis are in the medial part of the frontal lobe and those involved in depression in the central part.

It was noted that it was two to four weeks before some patients reached the maximum improvement. Many general reactions were noticed as a result of these operations, such as pain when the central white substance is destroyed, and after operation some complained of headache and many vomited and became somnolent. Also noticed after operation were many neurologic symptoms such as fibrillary twitchings, loss of sphincter control, mild diarrhea, myosis, and anisocoria.

Psychic changes noticed after operations were apathy, loss of initiative, stereotyped movements, catatonia, mutism, and many others.

The book is of historical interest but these early operative methods are now quite obsolete. Many authors are referred to by name, but no references are given.

Textbook of Gynecology. By Arthur Hale Curtis, M.D., Professor, Department of Obstetrics, Northwestern University Medical School. Pp. 755, with 455 illustrations. Philadelphia, 1946, W. B. Saunders Company. $8.

This textbook continues to be one of the best of its kind. The splendid description of pelvic anatomy is unsurpassed in any textbook. This continues to be one of the outstanding features of the book. Almost everyone is familiar with the previous editions, consequently, comment is reserved for the changes which have been made.

The author has changed the sections concerning endocrinology and its relation to uterine bleeding. The chapter dealing with gonorrhea has been reorganized with special reference to the new therapeutic agents. The section on sarcoma of the uterus has been extensively and well rewritten. The author has also rewritten the chapters dealing with the Brenner tumor and with teratomas. A completely new heading concerning the adrenal-like tumors of the ovary has been added. The author has very wisely stressed the importance of urinary incontinence and illustrates methods of repair. He mentions a bit about the importance of the Rh factor in repeated transfusions. However, one wishes that more emphasis might have been given to the problem of the Rh factor in general—especially the importance of preventing sensitization of girls and women in the childbearing age.

This book continues in its high place as a text and can be recommended.

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